The Weasel. A paper to be presented March 19, 1945 before the Society of Automotive Engineers. H. E. Churchill. March 19, 1945.

THE "WEASEL"

By H. E. Churchill

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Webster defines the Weasel as a small, elongated, reddish-brown quadruped which, in cold regions, turns white in winter. The noun assumed a sinister meaning shortly after Pearl Harbor. While the Japs were stealthily sneaking up the Aleutian Islands, occupying Kiska and Attu, and bombing Dutch Harbor, simultaneous engineering design, development, and production planning was going forward secretly at South Bend on a light-weight, low-unit ground pressure cargo carrier designed primarily for snow operation. The code word "Weasel" was appropriately applied to the project.

On May 17, 1942 the project was outlined by members of the British and United States Army General Staffs and the Office of Scientific Research and Development to The Studebaker Corporation, which accepted the assignment. Such items as overall length, width, track length on the ground, and approximate gross weight were contained in the original preliminary specifications. A life expectancy of 1,000 miles, 95% snow and 5% hard ground, was established. Starting from scratch, the first experimental model was ready for road tests on June 24, 1942, just thirty-eight days later.

Testing in snow involved two self-sustaining expeditions headquartered in the snow fields of the Columbia Glacier. Test specimens and equipment were often flown in to eliminate transportation delays and on one occasion a complete vehicle was carried by Army

Air Transport to the locality of the test fields.

The first experimental vehicle (Fig. 1) was designed to be used for either snow or water operations. A tunnel stern and propeller, driven from a power take-off mechanism in the power plant, were employed for water propulsion. The vehicle was 196" long, 60" wide, and had a silhouette height with the top down of 50-1/2". The track was front driven by a controlled steering differential and the power plant located approximately amidships. Eight bogie wheels, arranged in four pairs per side, carried the vehicle load on the flexible-cable, band-type track. Each pair of bogies was connected by longitudinal semi-elliptic springs pivotally anchored to suitable outriggers attached to the hull. This vehicle had provision for a crew of two and storage space in the hull sponsons for their necessary equipment and supplies. The vehicle weighed approximately 7,000 pounds with full cargo load. The suspension provided 89" of track on the ground and a 45" tread, giving a length of track on the ground to tread ratio of 1.97. Each track was 15" wide and, on the basis of area of track in contact with the ground, a unit ground pressure of 2.25 pounds per square inch was obtained.

Steering was very difficult and practically impossible because of the high length of track on the ground to tread ratio. Maximum speed was below expectations because of high rolling resistance and low power to weight ratio.

To meet certain strategic requirements and because of the undesirable characteristics as determined from initial tests, changes in specifications were made during the design of the first model. The second design (Fig. II), construction of which was carried on concurrently with work on the first design, was later approved and released to production. Several hundred of these vehicles (Fig. V), known as the model T-15 or M-28, were produced. Propeller propulsion in water was abandoned and the overall length was reduced to 128" in order to reduce vehicle weight. The power plant was located in the rear but the front track drive was retained. Even though the overall length of the vehicle was reduced, no appreciable change in cargo volume was made. The length of track in contact with the ground was reduced to 62", giving a length of track on ground to tread ratio of 1.6. This ratio overcame the steering difficulty experienced with the first model. This ratio is comparable with other heavier track-laying types of vehicle. The vehicle loaded had a gross weight of 4600 pounds. The track width was increased from 15" to 18" which, on the basis of track area in contact with the ground, gave a unit ground pressure of 2.0 pounds per square inch at 0 penetration. Because of the extreme flexibility and width of the tracks, considerable work was done to reduce their tendency to throw. The suspension consisted of four bogies per side (Figs. III & IV), arranged in pairs and connected together by compound semi-elliptic springs which were pivotally mounted to outriggered cross members which formed a part of the main hull framework. The final design bogie, as released to production, consisted of cambered bogie wheels mounted in pairs and pivoted on their connection with the suspension springs. The cambered bogie wheel and guide flange construction provided a point contact with the track guide lugs but also produced a diverging guide throat which gave more clearance for variations in the angle of approach of the track guide to the bogie over rough surfaces.

Certain deficiencies in construction were noted as testing and development on this model progressed but, because of the urgency for production vehicles, it was impossible to eliminate these deficiencies and maintain production. As service experience with this extremely low-ground-pressure unit began to accumulate, it was thought possible to extend its usefulness for operations in swamp and muddy terrain over or in which wheeled and high-unit-pressure vehicles could not operate. It was apparent that a complete redesign was justified. Among the major items to be improved in the redesign of the vehicle were the following:

(1) Increase life.

(2) Reduce rolling resistance.

(3) Improve cooling.

(4) Increase flotation or effective area of track in contact with the ground.

(5) Improve spring suspension.

(6) Improve hill-climbing ability.

(7) Increase cargo capacity.

These improvements were incorporated in a third design (Fig. VI) vehicle known as the M-29, which is currently in production. Unlike its predecessor, the power-plant is installed in the front and track drive thru the control differential is located at the rear - just the reverse of the T-15. Driving controls are located on the left side of the vehicle. Approximately the rear half of the water-tight hull (Fig. XXII) is clear space for cargo or special equipment. Seating is provided for three passengers plus the driver. Cooling air is taken in at the front of the vehicle and passes thru a tunnel in the hull, discharging upward thru a suitable duct at the rear. Later modifications (Fig. VII) consisting of detachable bow and stern cells to add buoyancy are currently being supplied as standard equipment. Certain design features of these units assist self-propulsion by means of the track only in deep water. This model has an overall length of 192-1/8", and is equipped with 20" tracks located on 45" tread center. 78" of track on ground gives a unit pressure of 1.91 pounds per square inch on the basis of track area in contact with the ground. The vehicle is suspended on four semi-elliptic transverse springs, the anchorages for which are a component part of the hull framework. Eight bogie wheels per side (Fig. VIII) carry the load. These bogie wheels are pivotally attached to the suspension (Fig. IX) and connected rigidly in pairs by forgings.

In our consideration of fundamental design characteristics for the M-29C and to increase life of the vehicle without the addition of considerable weight, it was apparent that shock loading would have to be reduced in order to increase vehicle life. Various types of suspension (Figs. X, XI, XII, XIII & XIV), in which lower bogie wheel spring rates would be feasible, were considered. The wheel rate of the M-28 was about 600 pounds per inch, as compared with approximately 150 pounds per inch on the M-29C. This reduction in wheel rate is partially accomplished by increasing the number of points of suspension from two to four and by the use of the independent type of wheel suspension obtained with the cross spring design. The primary hull construction is built around a backbone or keel section consisting of longitudinal beams to which the spring supports are attached. The longitudinal beam construction carries the column or compression loads imposed by track forces as well as vehicle weight transmitted to it through the closed spring suspension.

Rolling Resistance

The T-15, as designed and produced, had several inherent characteristics of the track and suspension system which contributed to roughness and high rolling resistance of the vehicle. These factors all tended to reduce speed and acceleration. Width of track plate, weight per unit length of track, grouser action when entering and leaving the ground, and mass distribution were some of the items believed to contribute to roughness and high rolling resistance. Drift tests showed a 20% reduction in rolling resistance when the grousers were removed from the production track. Qualitative tests also indicated that rolling resistance lowers as the width of track plate or pitch is reduced. Results of some of the factors investigated follow in detail:

(a) Track Plate Width

Tracks incorporating 3" and 4-1/2" wide plates were produced experimentally and tested in comparison with the 6" plate used on the T-15. Qualitatively, the 3-1/2" plate track was much smoother in operation and approximately 10% lower in rolling resistance than the 6" plate track. Endurance tests revealed lack of bending strength in the 3-1/2" wide plate. It was also unstable as a platform in snow. Tests in deep wet snow showed excessive plate rocking with this width of track plate. The 3-1/2" track plates failed after only fifty-seven miles of operation on the Proving Ground endurance course. It was also determined that a snow clearance hole is necessary to prevent icing, even with a single-pitch construction. Subsequent test results on the M-29 indicate that

4-1/2" plate width is about the minimum that can be used with this weight vehicle if adequate strength and plate stability in snow are to be maintained.

(b) Reduction in Track Weight by using "snowshoe" type of Plate.

Experimental samples of a "snowshoe" type design of plate employing a rectangular tubular frame with an expanded metal center section were built and tested in the laboratory for strength in bending. It was believed that the expanded metal center section would eliminate the necessity for grousers but static tests revealed that no weight saving could be effected if comparable strength in bending were to be maintained. No further consideration was given this item because of the unsatisfactory results of bending tests.

(c) Action of Track Plates and Grousers when contacting and leaving the Ground.

Observation of track patterns in snow and soft ground indicates that considerable available power is absorbed by the shearing action of the grouser when it enters and leaves the road surface. This is also evidenced in some designs by plate rocking as the bogies roll over the track. Graphic analysis of this action has been made and the effect of changes on angle of approach and retreat, as well as grouser location, have been studied. These studies indicate that:

(1) The greatest loss occurs when the grouser is placed at the leading edge of the plate.

(2) Loss or interference is minimized as the angles of approach and departure of the track, relative to the ground line, are reduced.

(3) A grouser whose cross-section approaches an involute form and located midway between the leading and trailing edges of the plate, shows the least interference when entering or leaving the ground.

(4) The shortest height of grouser consistent with satisfactory performance is desirable.

The following three track designs were built and tested in comparison with the standard T-15 track:

(1) 3" plate width with centrally located 1-1/2" high grouser and no stabilizer bars.

(2) 6" plate width with centrally located 1-1/2" high grouser and no stabilizer bars.

(3) 6" plate width with 1-1/2" high grouser located on trailing edge of plate and employing two stabilizer pads of rubber located under the track bands to eliminate plate rock on hard ground.

The 3" plate central grouser track was quieter and smoother in operation on snow than the 6" width plates of production or either of 2 or 3 above. However, this track had serious plate-rocking characteristics which noticeably reduced the climbing ability of the vehicle in snow. Plate rocking in this track caused the grouser to shear, in a horizontal plane, the compacted snow under the tracks as the bogies rolled over the plates and thus causing a noticeable and serious loss in traction. This track was also more susceptible to throwing due to icing (Fig. XV), because no snow clearance holes could be provided in the center of the plate, without too great a sacrifice in beam strength of the plate. Icing occurred principally under the sprocket teeth.

Track #2, with 6" wide plate and central grouser location, had no serious plate-rocking characteristics in snow but was very unstable on hard ground. This condition was eliminated in track #3 by the addition of longitudinal rubber pads as stabilizers and which were later released for production on the T-24. This track, with central grouser location, when compared with the production T-15 or #3 track above, showed much less disturbance of the track pattern due to grouser interference.

The 6" plate, #3 track above, with the grouser at the rear, did not show any appreciable improvement over the production design except the stabilizer blocks or track pads reduced track noise on hard ground because the rubber pads carried all track load at zero penetration and prevented contact of the steel grouser with the ground. The track pads also showed a very slight tendency to reduce side slip on traverses in snow.

Results of rolling resistance tests indicated that:

(1) The rolling resistance per thousand pounds weight of the vehicle, with production tracks minus grousers, is considerably higher than for other track-laying vehicles, probably because this particular vehicle has a much lower gross weight and the work required to rotate the tracks is not proportional to the weight of vehicle.

(2) Rolling resistance increases with the addition of a grouser and also with an increase in plate width for given diameters of sprockets, idlers, and bogie wheels.

(d) Bogie Wheel Rolling Resistance.

Our investigations were concerned primarily with the effect of diameters of bogie wheels and the difference between straight and cambered bogies.

Laboratory measurements of rolling resistance were made by towing a trackless vehicle on production track bands placed parallel on a flat surface. The vehicle load was carried on the bogie wheels. The forces required to start movement and sustain movement or roll were measured for the various combinations tested. The results in terms of drawbar pull per thousand pounds weight are given in the following table. All data are based on a 3,000# vehicle test weight.

Case No.	Condition	Rolling Resistance lbs./thousand Starting	Rolling
1	T-15 8" bogies cambered 22-1/2°	27.0	17.0
2	Same as (1) except caster angle removed from front bogie	20.0	13.0
3	Same as (1) except rolled on wood tracks	18.3	16.0
4	Same as (2) except rolled on wood tracks	16.0	12.0
5	Same as (1) except parallel bogies 8" Dia.	20.5	13.0
6	Same as (1) except parallel bogies 12" Dia.	15.0	9.3
7	M-29 production vehicle equipped with eight 8" diameter bogie wheels per side	24.0	18.0

These results indicate the effect of bogie wheel design on rolling resistance. Parallel bogies in case 5 show a 23% reduction when compared with the same 8" diameter cambered bogies in case 1. Bogie diameter effect is indicated by the 25% reduction in rolling resistance of the 12" diameter bogies in case 6 when compared with the 8" diameter bogies of case 5. These data do not include the resistance of the track and drive train; therefore, the percentages quoted are not applicable to total vehicle resistance. They do indicate quite clearly the definite improvement to be expected by the use of straight bogies. It may also be noted that sixteen parallel 8" bogies in case 7 have about the same rolling resistance as eight angled bogies indicated in case 1.

Bogie wheel load vs. rolling resistance tests were made in which angle bogies, 12" diameter parallel bogies and a prototype of the M-29 incorporating eight 8" diameter parallel bogie wheels per side were compared. The results are graphically illustrated in Fig. XVI.

Eight parallel bogies per side have about the same resistance, 20#/1,000, as four angled bogies per side of the same diameter. Four 12" diameter parallel bogie wheels per side reduce rolling resistance of the wheels on the track approximately 50%. Assuming a total rolling resistance of 100#/1,000 as an average for this vehicle, the 10-pound reduction obtained with 12" diameter wheels then becomes only 10% of the total resistance. However, flotation and climbing tests indicated the desirability of more bogies per side for the redesigned vehicle and it was decided that the advantage of eight 8" diameter parallel wheels per side justified their use since the rolling resistance was no greater than four angle bogie wheels. In fact, it may be observed that the resistance is less for vehicle loads in excess of 4,000#.

Climbing Ability.

Mass distribution, unit load per bogie, and track speed are major factors controlling maximum gradeability of a vehicle operating over a compressible or displaceable medium. Vertical and longitudinal location of center of gravity, which in turn have a direct effect on unit load per bogie, assume first order of importance as demonstrated by qualitative test results. The model M-28, with a high center of gravity located to the rear of the centerline of track area, always ran in soft snow with a "bow high" aspect even on level ground (Figs. XVII and XVIII). This not only caused high rolling resistance due to increased flexing of the track and high penetration but also reduced the tangent grade which the vehicle would climb without loss of steering control. The principal portion of the driving force was obtained from the rear part of the track because of the high unit pressures under the rear bogies. Hence, as soon as the force required to drive exceeded the shear strength of the terrain on which the climb was being made, track slippage would be encountered with a resultant loss in directional control. This produced what we termed a "falling off" effect. By providing more points of support on the track, moving the center of gravity forward and lower with respect to the ground, maximum grade ability of the M-29 is approximately 20% better than its predecessor, the M-28. This improvement is chiefly due to lower unit bogie load and better mass distribution obtained by moving the center of gravity forward and lower with respect to the ground. Following is a discussion of several other items affecting gradeability.

(1) Increased Power

Test experience in snow has demonstrated that the M-29 has ample power for climbing in snow; in fact, maximum gradeability in soft snow is obtained at part throttle by running in low gear low transfer at as low a track speed as possible, consistent with smooth engine performance. Increased power would thus be beneficial only in obtaining higher vehicle speeds on level snow. Designs and studies were made incorporating an engine with 30% increased torque. This design was dropped from further consideration because; (a) the power plant weight increased 200 pounds, (b) the increased torque would necessitate complete redesign of all units in the drive train, resulting in a further increase of 150 to 200 pounds, and (c) the total increase in vehicle weight probably would result in a reduction in overall performance.

(2) Rear Drive vs. Front Drive.

A rear drive arrangement for this particular type vehicle is advantageous and desirable in obtaining a simple drive train which permits disposition of the major vehicle driving and power units for a good location of the vehicle center of gravity. Direct comparisons of rear drive vs. front drive vehicles were made. No actual detrimental effect in performance could be observed in the rear drive vehicle. Several observations made during tests are recorded herewith

(a) The front idler wheel mechanism is not subjected to track driving loads in forward operation.

(b) Track tension is more uniform in forward operation because the reaction to the driving force is not taken in the tension mechanism.

(c) Slack track, between the front bogie and the front idler under forward track load, is eliminated.

(3) Overall Gear Reductions in Driving Train.

The production ratios available in the M-28 were necessarily fixed by the transmission and transfer cases which were in production. These ratios overlapped, notably in high transfer first gear and low transfer third gear. Test experience in climbing indicated the highest ratio available was too low for good climbing ability in soft snow.

The following tabulation shows the comparison of torque multiplication and vehicle speed at 4,000 r.p.m., based on a 5.85 axle ratio for the M-28 and 4.87 ratio for the M-29.

Gear		M-28		M-29	
Transfer Case	Trans.	Torque Multiplication	M.P.H. @ 4,000 r.p.m.	Torque Multiplication	M.P.H. @ 4,000 r.p.m.
High	3rd	8.93	32.0	7.9	36.4
"	2nd	13.9	20.6	12.3	23.4
"	1st	23.8	12.0	21.0	13.7
Low	3rd	17.73	16.1	24.9	11.5
"	2nd	27.7	10.3	38.8	7.4
"	1st	47.2	6.05	66.2	4.33

Tests of the M-29 ratios gave better hill climbing and high speed performance under all conditions than the M-28 ratios. Under maximum climb conditions, or low transfer low gear operation in soft snow, the M-29 track speed can be maintained 28% lower than the M-28 for equal engine speeds.

Flotation.

Unit ground pressures are specified in pounds per square inch. This value is obtained by dividing the gross vehicle weight by the area of track in contact with the ground. A figure thus obtained can only apply for hard surfaces in which no penetration occurs and if the track is a rigid structure supporting a load whose center of gravity is in the center of the track area in contact with the ground. Bearing pressures thus obtained for vehicles which operate in a compressible medium are therefore fallacious unless the track is a rigid structure and then would only apply for a horizontal vehicle position. Due to bogie spacing, flexible tracks assume a reversed catenary shape in snow or mud. Standing waves produced by unequal bogie load distribution and concentrated bogie loads on localized sections of the track were also observed. The standing wave is due to a rearward location of the center of gravity. No standing wave is observed in vehicles with center of gravity forward because the most heavily loaded bogie runs over the compressible medium first. Subsequent passage of the lower-loaded bogies, therefore, does not produce further compression of the snow and consequently the only deviation from a straight track is due to the concentration of loads in sections of the bands adjacent to the bogie wheels. These track conditions were demonstrated in snow by graphically measuring actual track shapes under various load distributions. The various track shapes were demonstrated statically on the same vehicle by running it into fresh snow. The snow was carefully removed alongside the track, exposing the track contour and photographed. The standard vehicle with rearward center of gravity and run forward showed high penetration under the rear bogies with resultant "standing waves" (Fig. XIX-A) in front of each bogie wheel. The vehicle was then run backwards into the same type snow which, as far as tracks were concerned, reversed the position of mass center relative to the entrance bogie. No "standing wave" (Fig. XIX-B) was observed because the highest loaded bogie entered the snow first. The reversed catenary did exist because of bogie spacing or lack of track rigidity. To assimilate a rigid track the vehicle was then run onto fresh snow over a one-inch board. No "standing wave" or reverse catenary was observed (Fig. XIX-C). Track distortion becomes greater on grades (Fig. XX) because the inequalities in bogie load become greater.

Since depth of penetration is a definite function of load and load distribution and since work is required to compress the medium, it is desirable to reduce the inequalities and thus minimize depth of penetration. Penetration at each individual bogie (Fig. XXI) on vehicles equipped with flexible tracks is a definite function of each bogie load. To reduce track flexure, it is desirable that the entering or leading bogie be loaded heaviest because succeeding bogies will roll over the compressed area without causing further disturbance of the track pattern. Excessive inequalities in load between the entering and succeeding bogies requires the expenditure of unnecessary work because an unnecessary amount of material is being compressed. Unit bogie loads of course are dependent on the number of bogies used and therefore the maximum number of bogies should be used on any vehicle intended primarily to run in compressible media.

The effect of number of bogies and location of center of gravity is illustrated in Figure XXIII. If we assume a vehicle weight of 4,000 pounds and a total track length on the ground of 75", this vehicle equipped with four bogies (Fig. XXIV) would have 200 pounds greater bogie wheel load on the rear than on the front if the center of gravity were 5" off the center line of the track. This same vehicle would have a 16% less maximum bogie load per wheel if the center of gravity were on the center line of the track. If the same vehicle were equipped with six bogie wheels per side (Fig. XXV) instead of four, loads per bogie wheel would be reduced approximately 33%. Again, assuming the same vehicle to be equipped with eight bogie wheels per side (Fig. XXVI), the bogie load per wheel would be reduced 50%. Since depth of penetration is definitely related to power required to drive, it can readily be seen that the maximum number of bogie wheels and a central or slightly forward center of gravity are definitely desirable.

Qualitative tests to determine the effect of increased track area were made on an M-28 equipped with a 24" wide track. Otherwise, the vehicle was standard except for an increased weight of 95 pounds due to the wider track. Following are the calculated ground pressures of the experimental and standard tracks as tested:

Vehicle	Track Width	Length on Ground	Vehicle Test Weight	Ground Pressure
#12	18" Std.	62½"	3598	1.60
#6	24"	62½"	3693	1.22

The above vehicles were tested in powdered snow approximately twenty inches deep. Both vehicles stalled on a 26% grade. While the 24% reduction in calculated ground pressure did not show any improvement in climbing ability, the penetration in level snow was less on the 24" track. These results further confirm the opinion that bogie loads, weight distribution, plate rocking, bogie spacing, etc. are paramount factors in flotation. During the testing of the 24" wide track the same characteristic "standing wave" was observed, either on level snow or in climbing a grade. The "staircase" or "standing wave" conformed with the bogie load distribution on the M-28.

Laboratory measurements of the ground reaction under each bogie wheel were made on a standard vehicle by placing jacks on platform scales and raising the bogie wheels until the scale loads at each bogie were equal to the calculated bogie load distribution of the standard vehicle. Track form was then graphically obtained. The results added credence to the theory that the standing wave or stairstep condition was due primarily to the inherent weight distribution and bogie design of the vehicle. A secondary reason for the wave was due to excessive unsupported length of track between bogies. The test results also lend substance to the suspected improvement in track profile in snow by the use of an increased number of bogies for better distribution of the vehicle load on the projected track area in contact with the ground. The test setup is illustrated in Fig. XXVII. Measurements were made under various conditions of track tension, vehicle load, driving torque, and rolling resistance. Bogie wheel loads were computed from the measured mass distribution of the vehicle with zero track tension. A plateless track was employed. Track tension was applied by dead weights and forces due to torque and rolling resistance were applied to the bands through spring scales. The test results are shown on the nine curves of Fig. XXVIII. The curves are drawn to the same scale and therefore graphically show the track profiles under the following conditions:

Curve No.	
1	Production M-28 Weasel.
2	Catenary due to track tension only.
3	Forces to produce a straight track at 500, 750, and 1000-pound track tensions under static conditions.
4	Vehicle load of 3400 pounds and track tensions of 500, 750, and 1000 pounds.
5	Vehicle load of 4000 pounds and track tensions of 500, 750, and 1000 pounds.
6	Vehicle load of 4600 pounds and track tensions of 500, 750, and 1000 pounds
7	Comparison of the above loads at track tension of 1000 pounds.
8	Vehicle load of 4000 pounds with track tension of 1000 pounds and a rolling condition of torque and resistance, each being 400, 800, and 1000 pounds. There is also a table of forces necessary to produce a straight track.
9	Vehicle load of 4000 pounds with track tension of 1000 pounds and a rolling condition of torque and resistance, each being 400 pounds. Notice the necessary movement of the bogie spring support on the spring to actuate the leverage to produce a straight track.

The results of this test show that:

(1) The track has a definite catenary due to the design of the vehicle and on which changes in vehicle load up to 4600 pounds have practically no effect.

(2) A variation in track tension does not change the track catenary, but has a definite function in the forces necessary to produce a straight track.

(3) Assuming that the vehidle track took its natural base on the ground, being from the rear wheel of the front bogie to the rear idler wheel, as in curve #2, that the front of the vehicle would be raised nine inches from its level position, having been upset on a five degree angle.

(4) The track catenary changes due to the forces of torque and resistance. A comparison of curves 3 and 8 show the change in forces to produce a straight line track when the vehicle is in motion.

(5) A straight line track under each bogie could be produced by the weight distribution of the vehicle if the front and rear bogie spring support were each moved to give the necessary leverage for overcoming the track tension as illustrated in curve 9.

(6) A straight track cannot be maintained in a compressible medium unless the loads are equal on all bogies or the maximum bogie load is carried at the front. In other words, the center of gravity of the vehicle must be at the center or to the front of center of the projected track area on the ground.

(7) The dynamic bow-high aspect of the M-28 in snow is due to the load distribution on the track, as shown in Curves 4 to 8.

Although the Weasel was originally designed for transportation over snow, its high mobility has widened its scope of service to such an extent that snow operations have become a minor part of the military usage of the vehicle. This would seem to indicate that factors producing high mobility in snow are also applicable to mud or any type of so-called "soft going". The author does not wish to imply that any of these factors have been investigated thoroughly enough during Weasel development to permit concrete evaluation of their relative importance. There is evidence that they are fundamental and probably influence the mobility of any track-laying vehicle regardless of size. We should have more fundamental knowledge about them.

Acknowledgment

The author wishes to acknowledge the splendid spirit and cooperation evidenced by the multitude of co-workers and associates interested in this project. Without it the development would have been impossible.

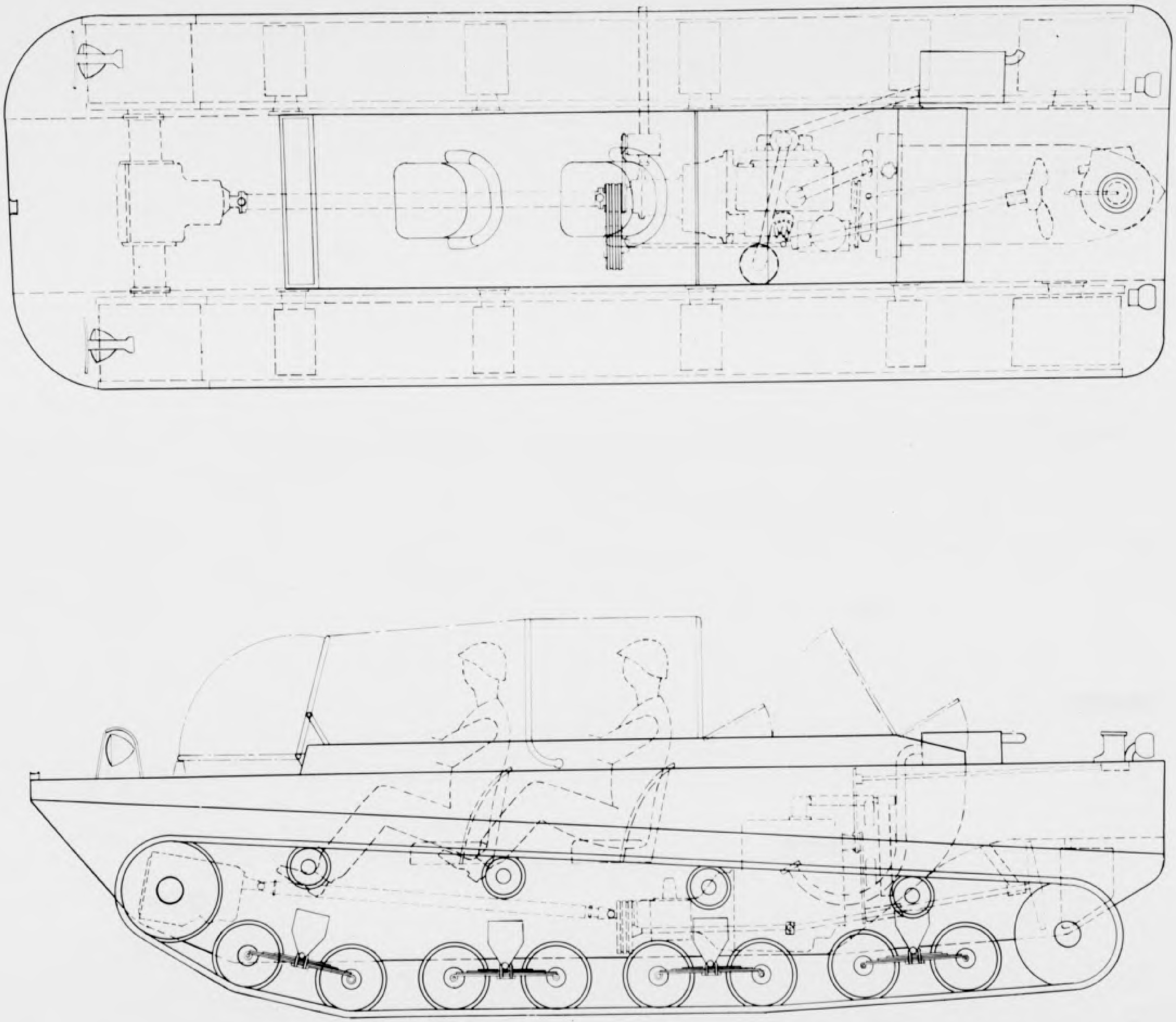


FIG. I

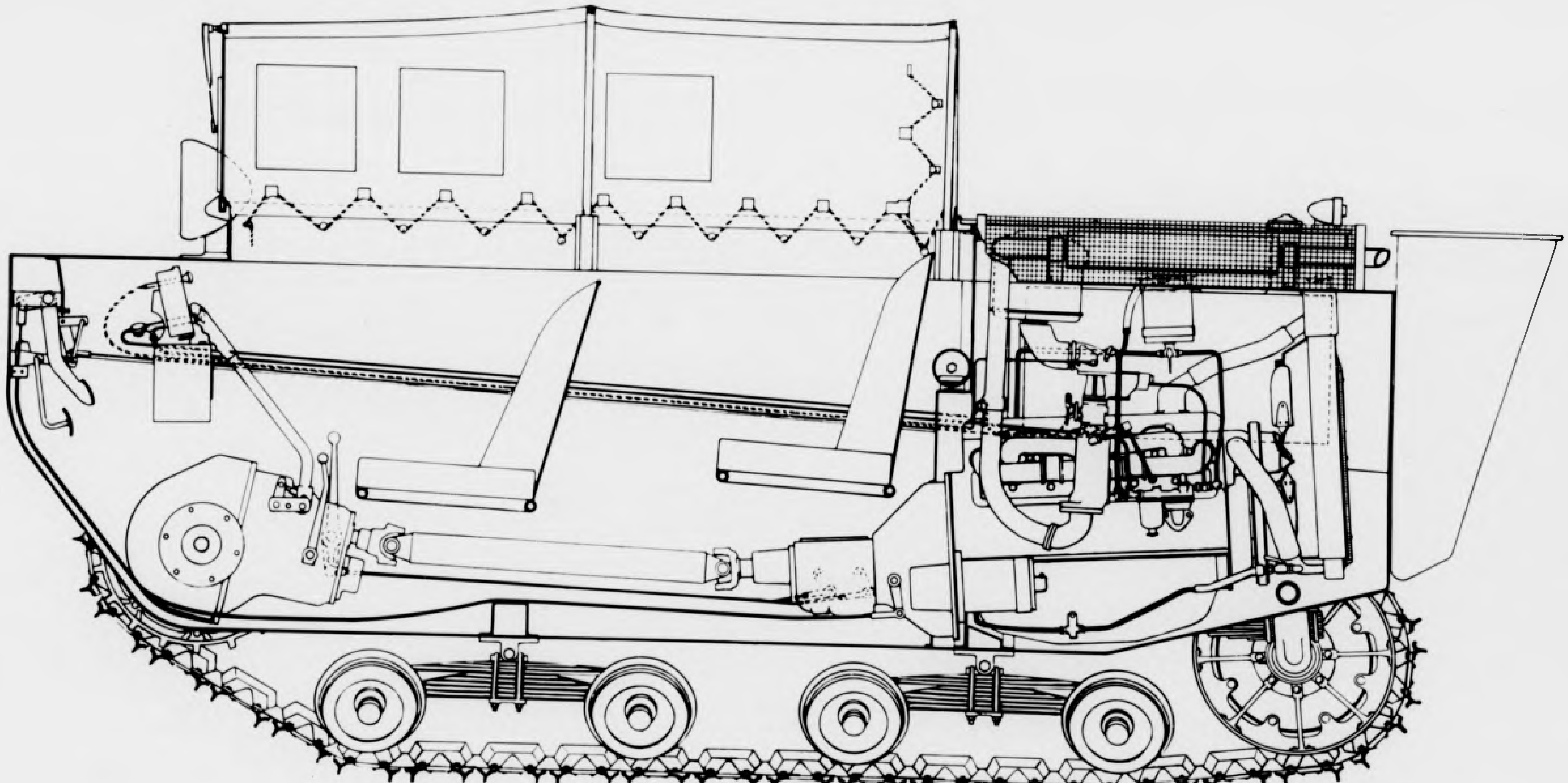


FIG. II

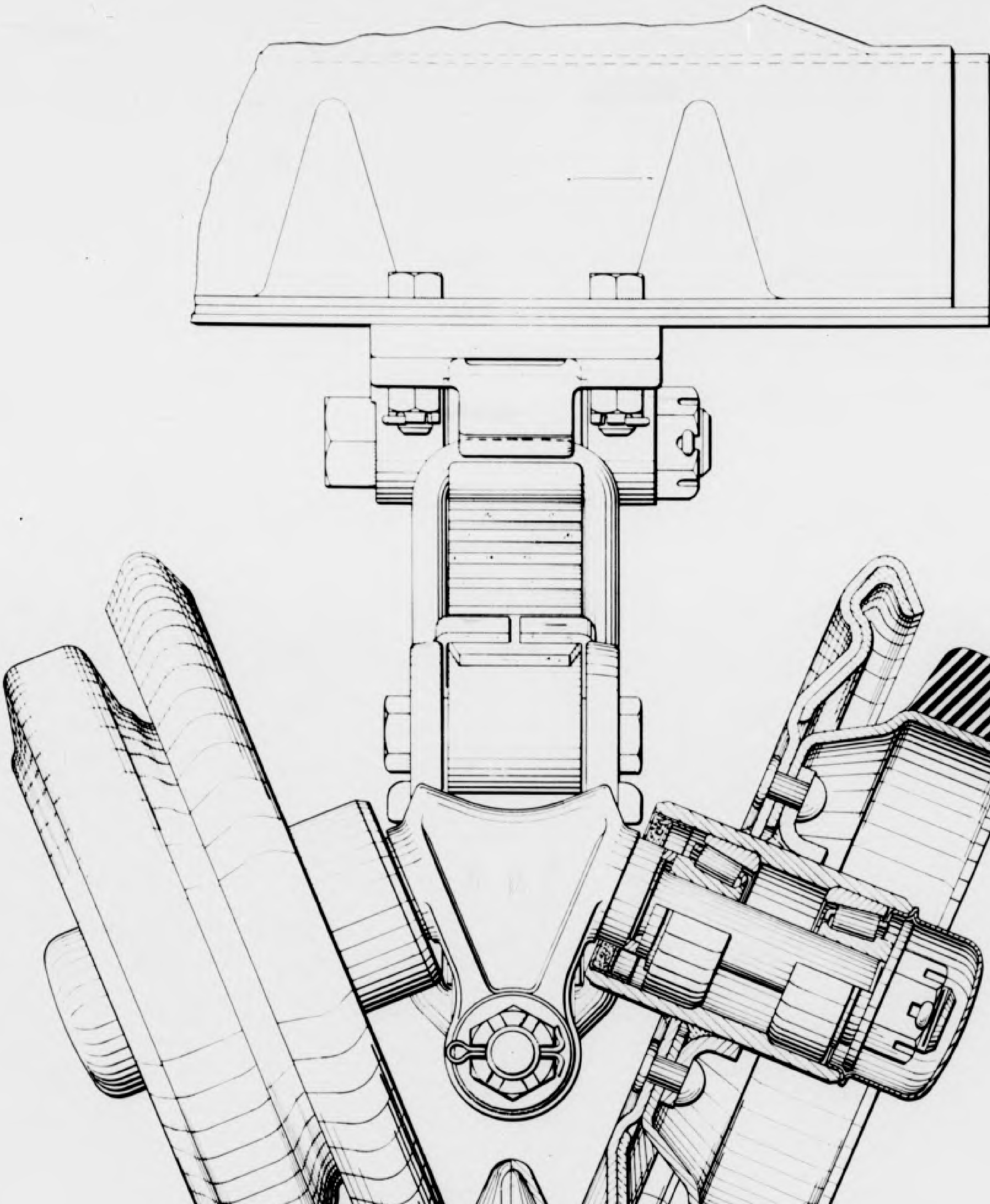


FIG. III

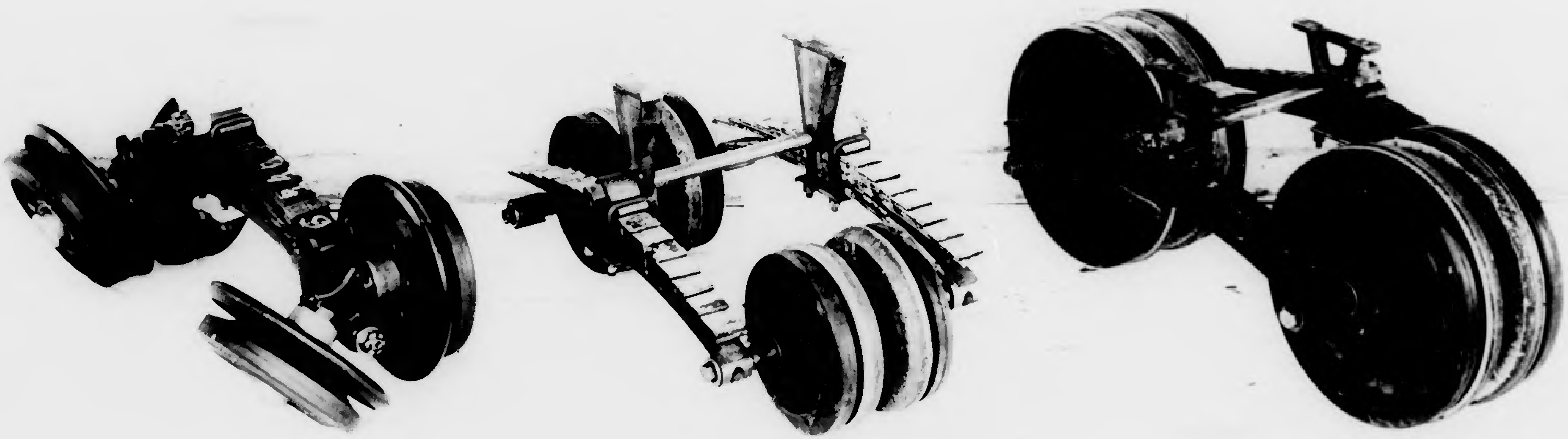


FIG. IV

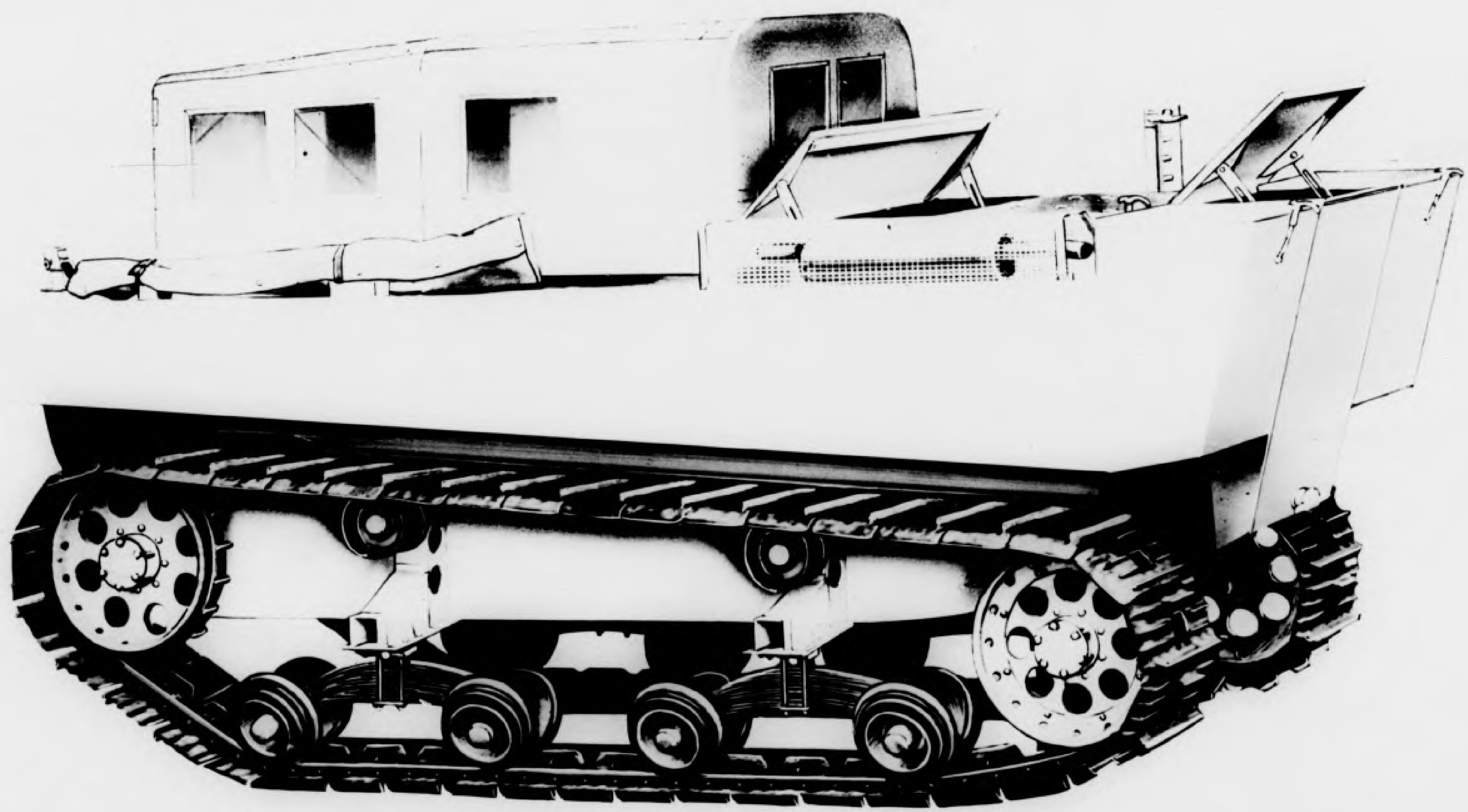


FIG. V

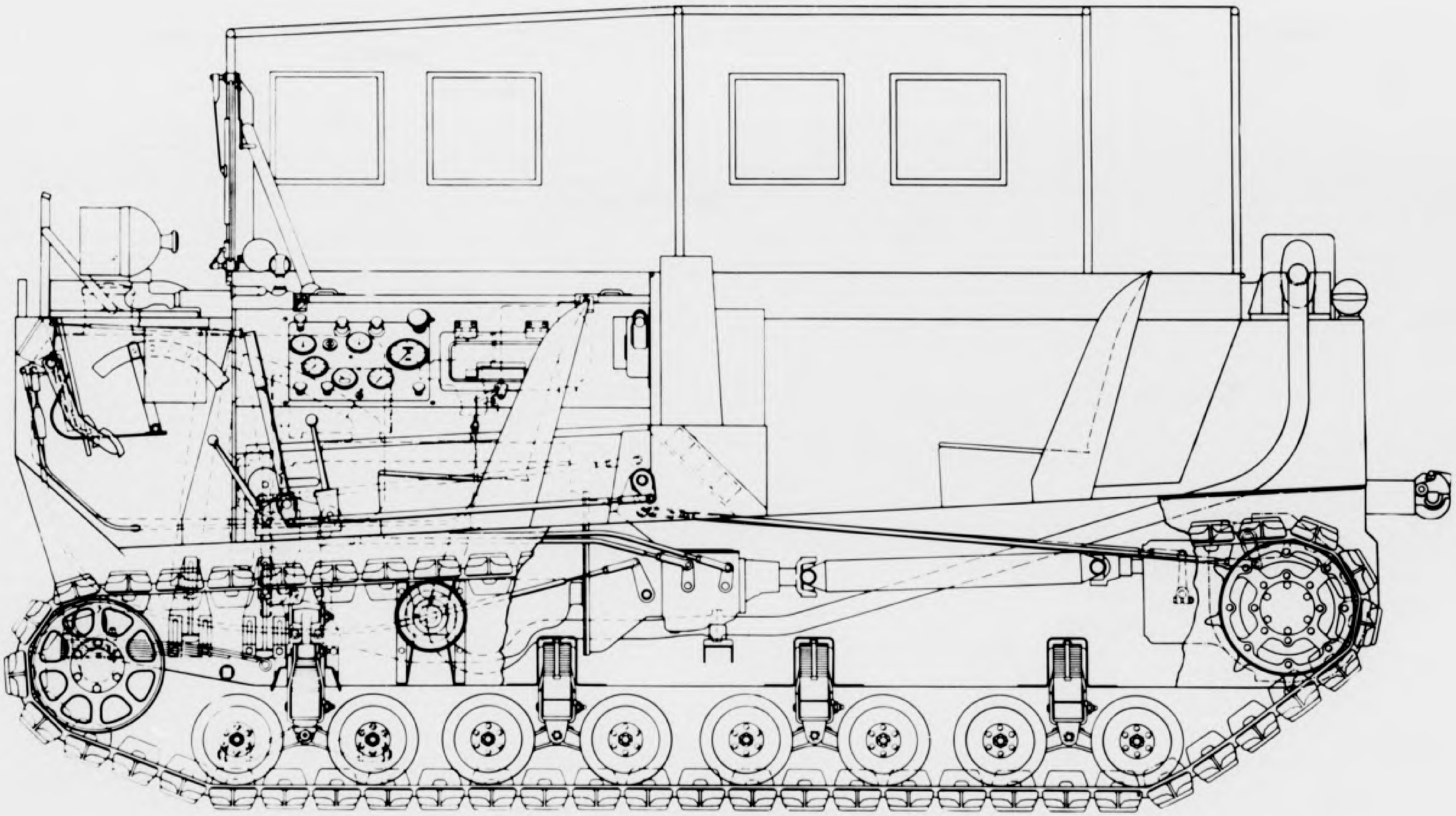


FIG. VI

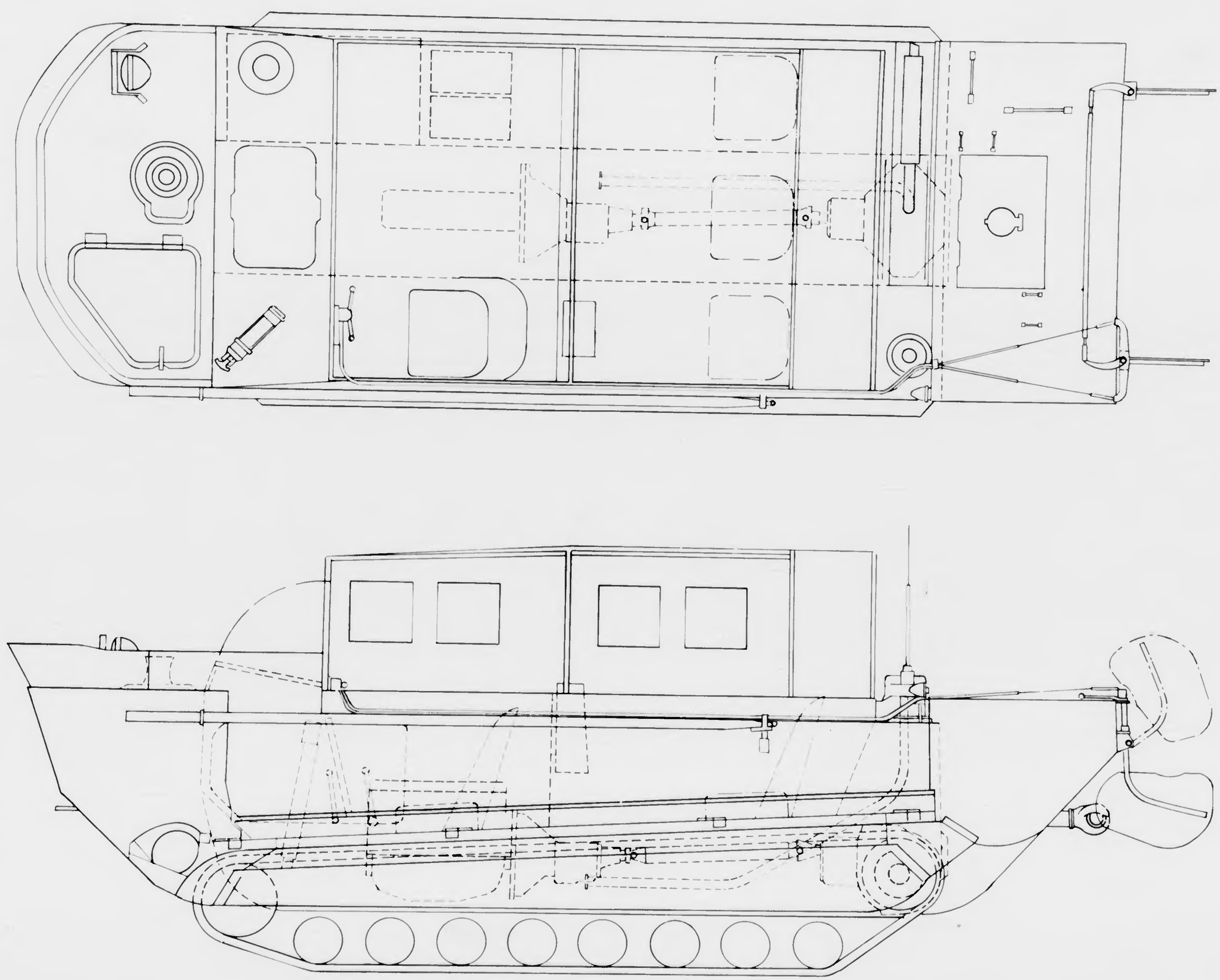
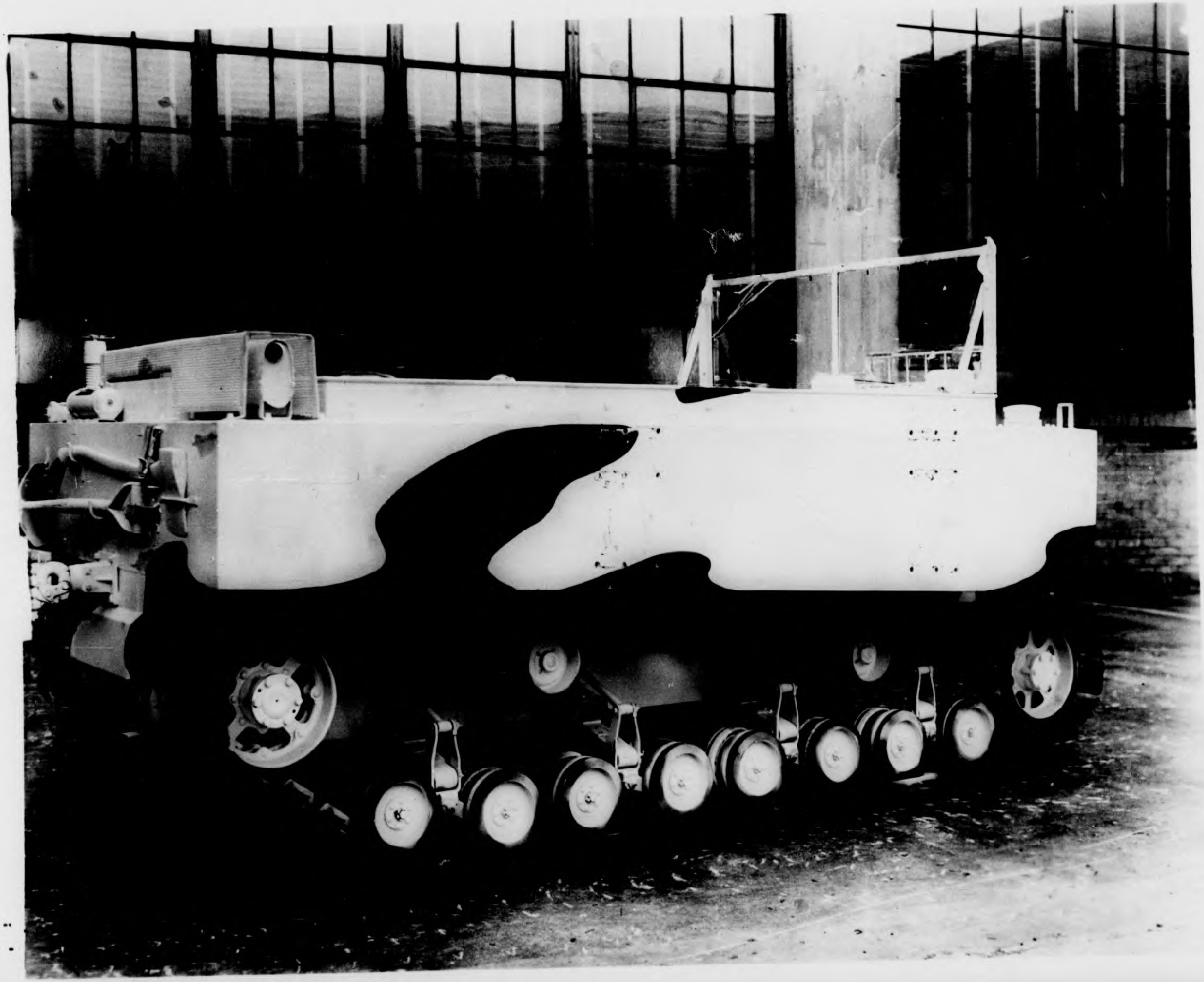


FIG. VII



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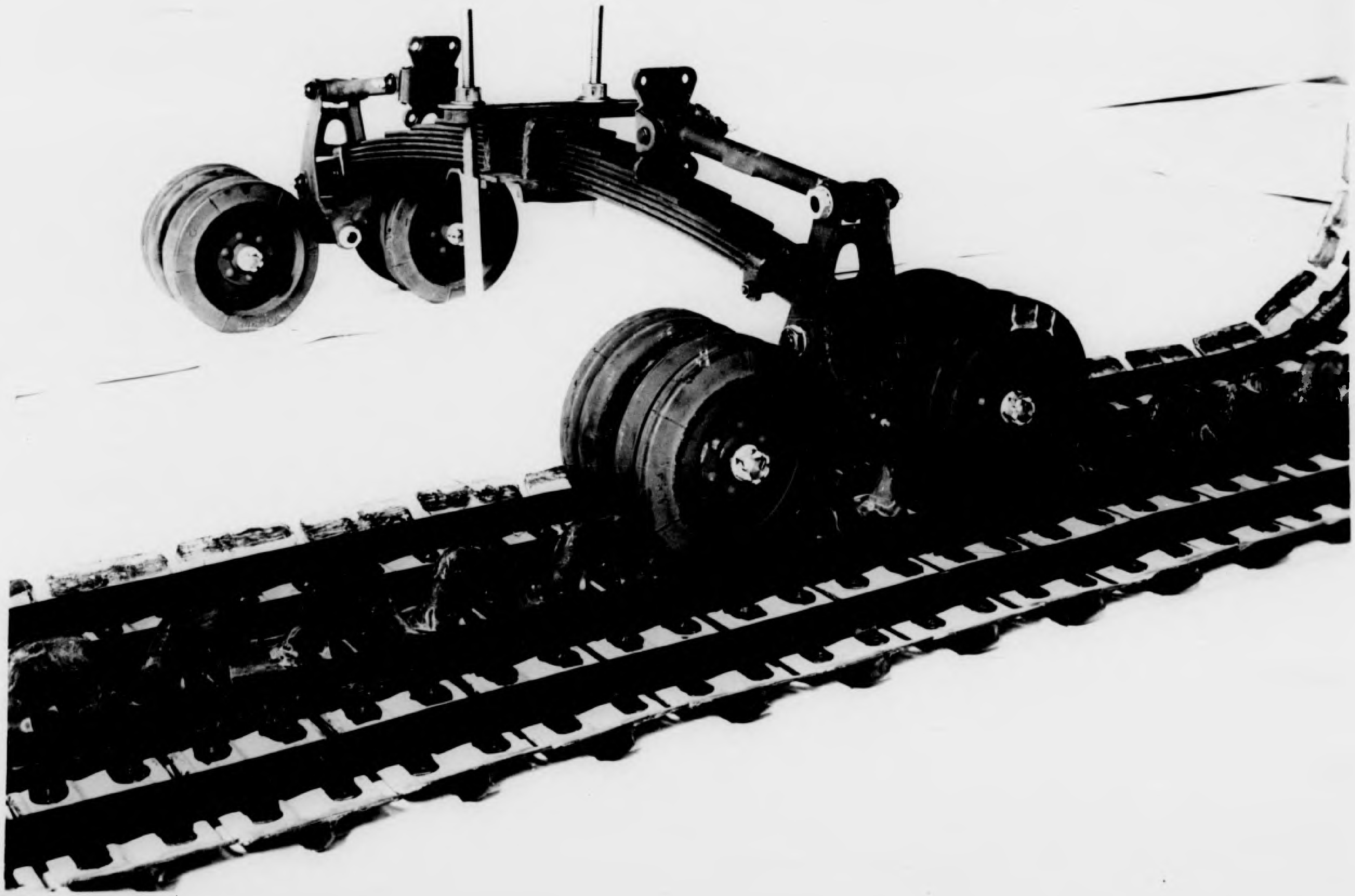
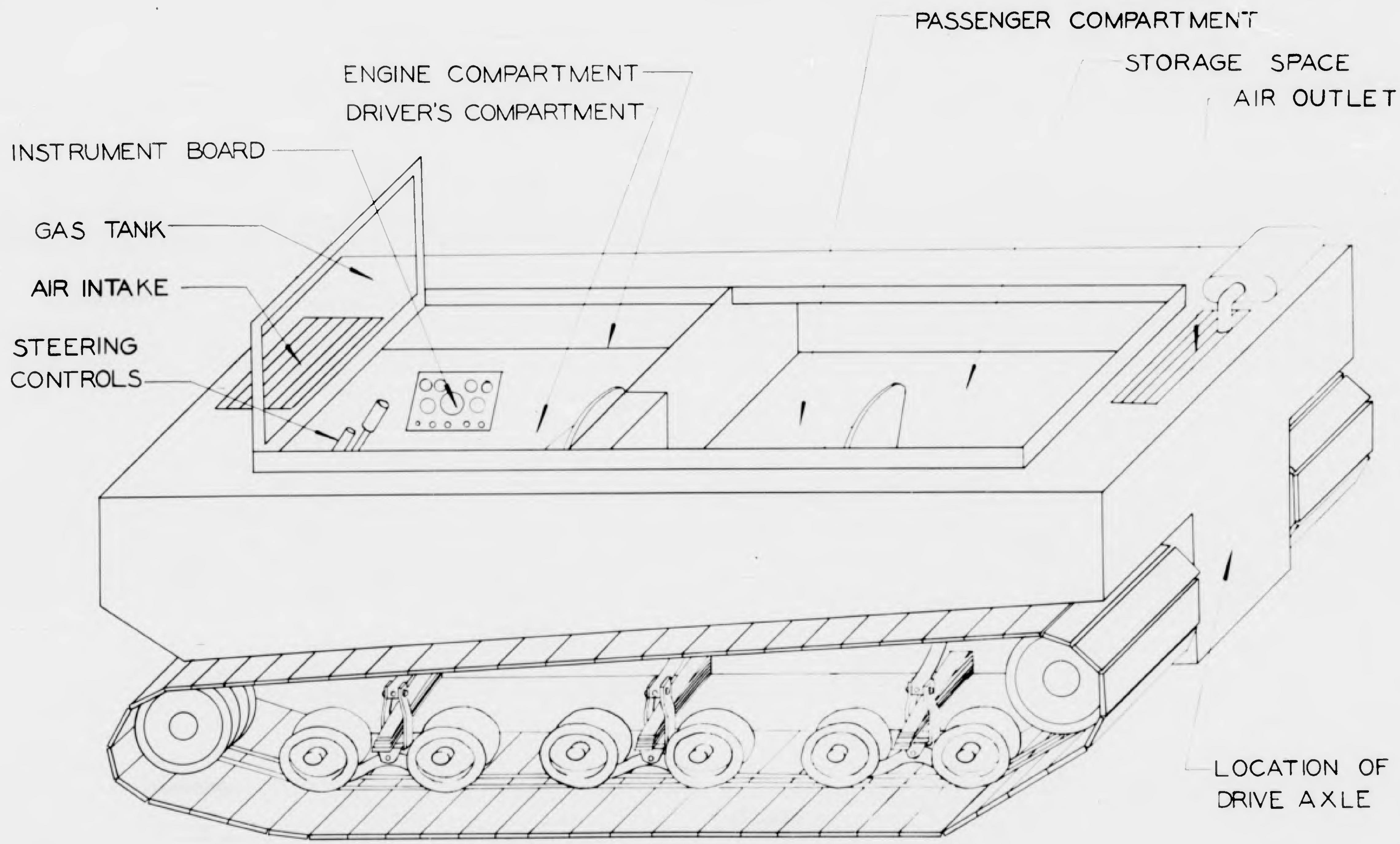
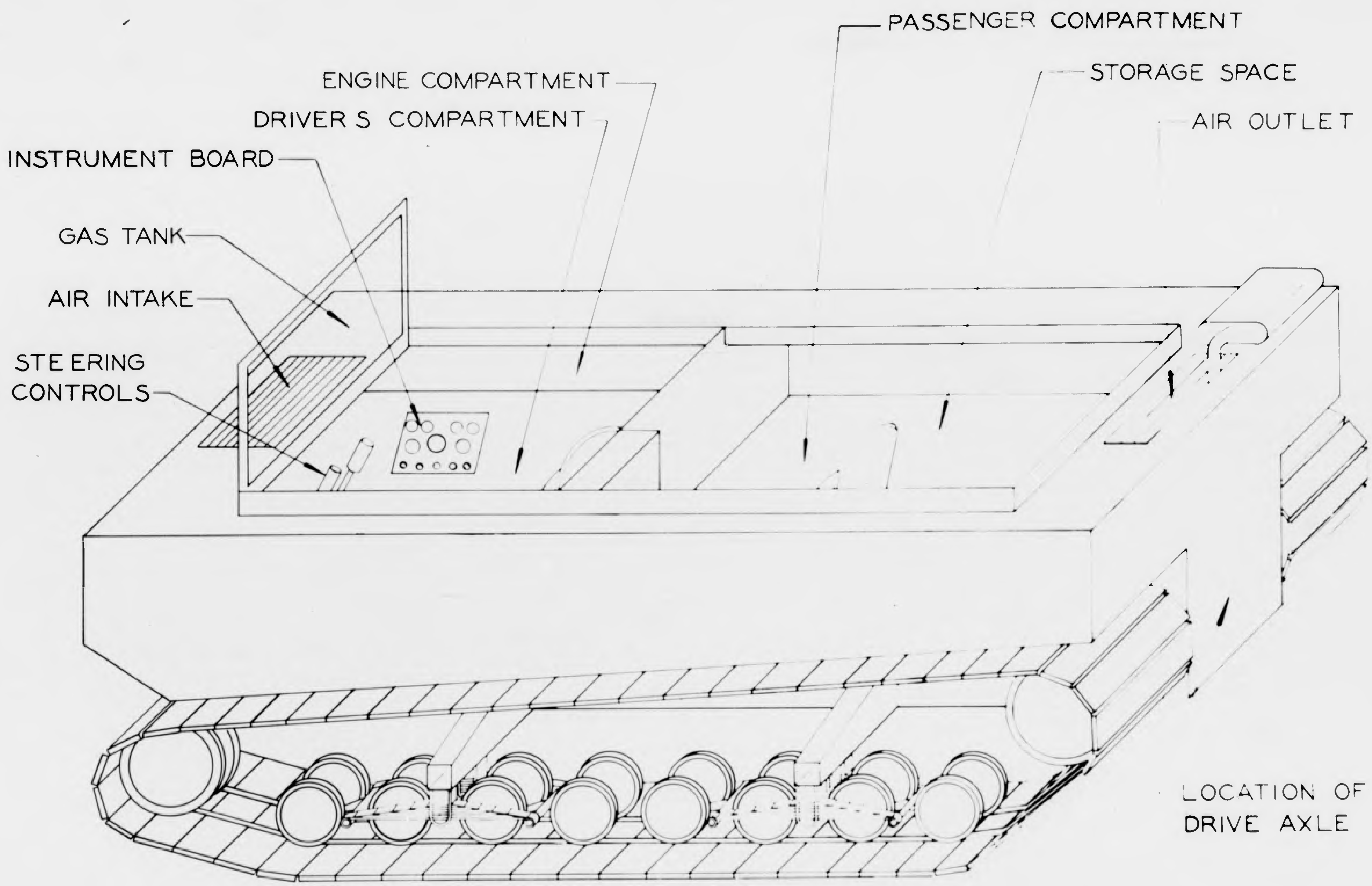


FIG. IX



ON EACH SIDE — SIX PAIRS OF ANGLE BOGIES
WITH TRANSVERSE SPRINGING

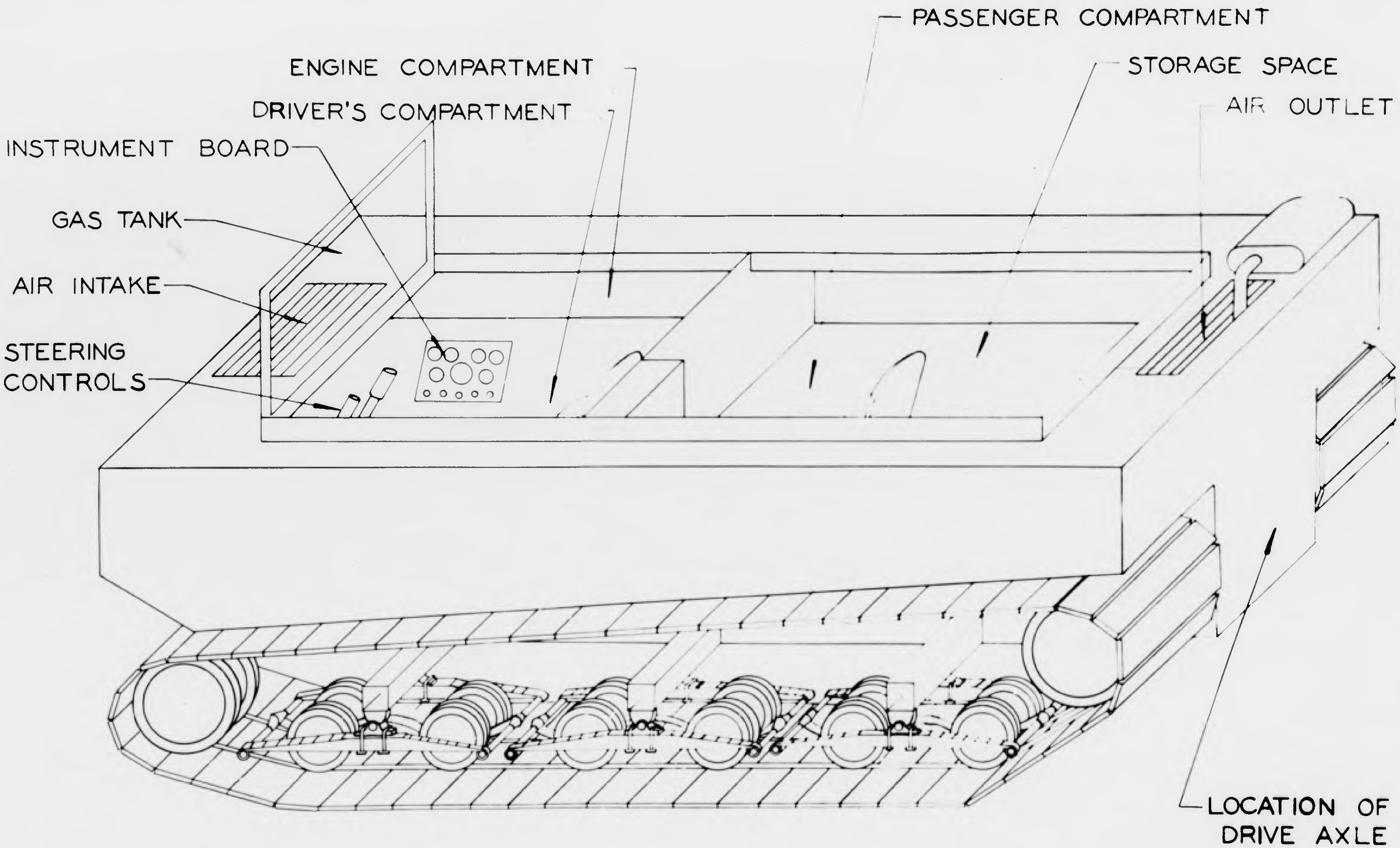
FIG.X



ON EACH SIDE — EIGHT PAIRS OF STRAIGHT BOGIES
WITH LONGITUDINAL SPRINGING

LENGTH OF TRACK ON GROUND 78 1/8
TOTAL GROUND CONTACT AREA - ZERO PENETRATION - 2968 SQ IN
UNIT PRESSURE - 1.57 LBS./SQ. IN.

FIG. XI



ON EACH SIDE — SIX PAIRS OF STRAIGHT BOGIES
WITH LONGITUDINAL SPRINGING

FIG. XII

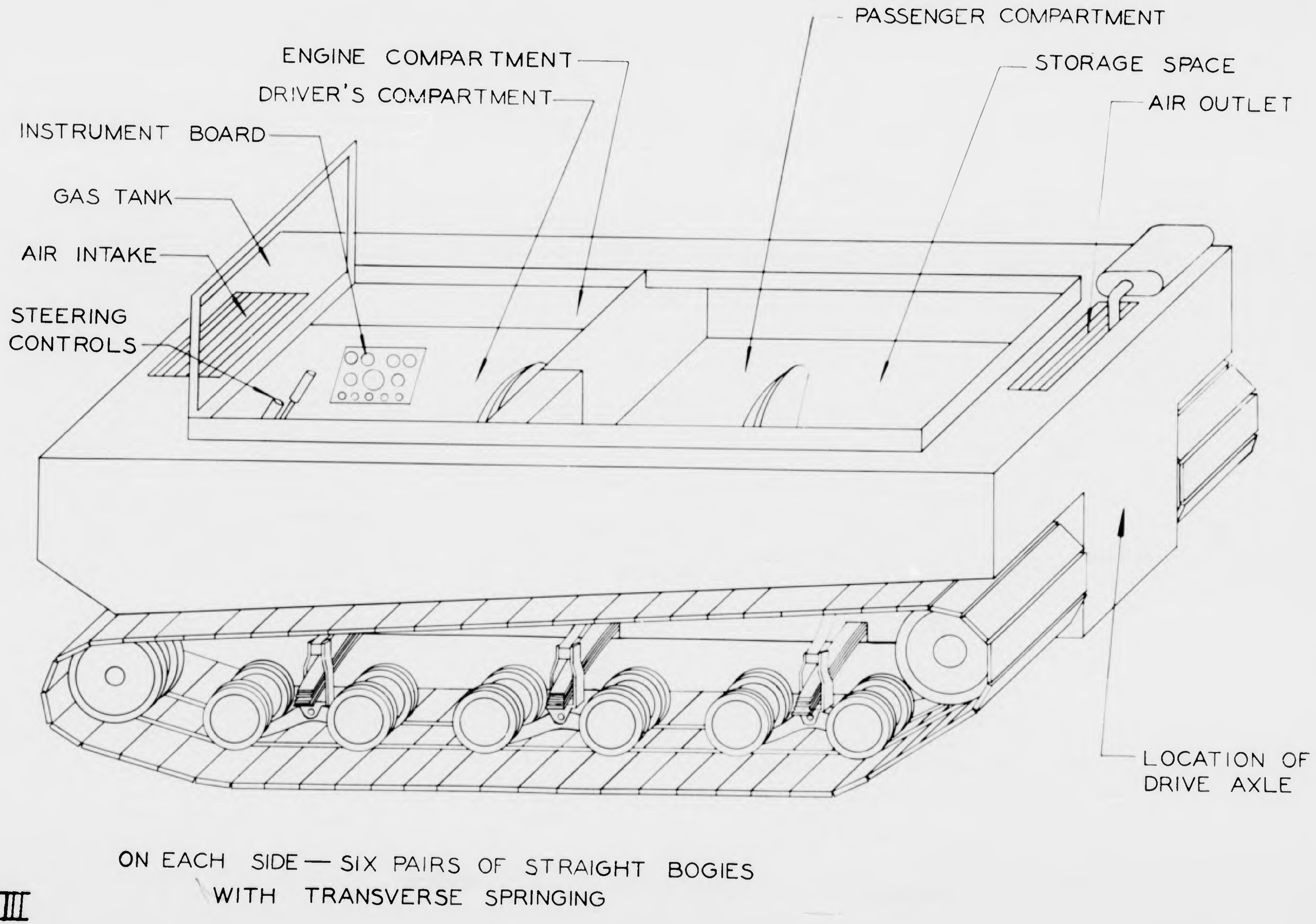
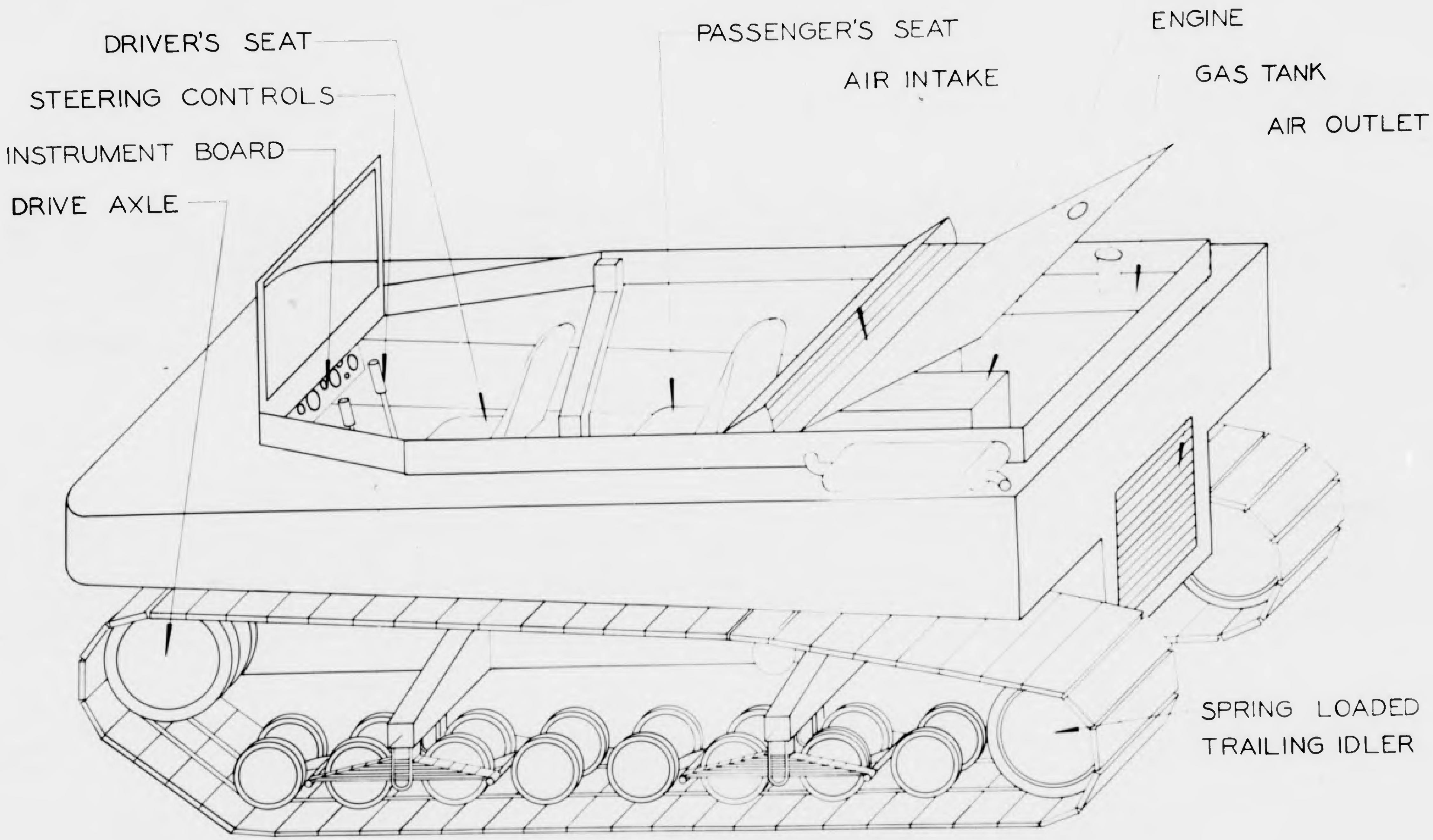

PASSENGER COMPARTMENT
ENGINE COMPARTMENT
STORAGE SPACE
DRIVER'S COMPARTMENT
AIR OUTLET
INSTRUMENT BOARD
GAS TANK
AIR INTAKE
STEERING
CONTROLS
LOCATION OF
DRIVE AXLE
ON EACH SIDE — SIX PAIRS OF STRAIGHT BOGIES
WITH TRANSVERSE SPRINGING

FIG. XIII



ON EACH SIDE — EIGHT PAIRS OF STRAIGHT BOGIES
WITH LONGITUDINAL SPRINGING
LENGTH OF TRACK ON GROUND 89 3/4
TOTAL GROUND CONTACT AREA 3231 SQ. IN.
UNIT PRESSURE 1.44 LBS PER SQ. IN.

FIG. XIV

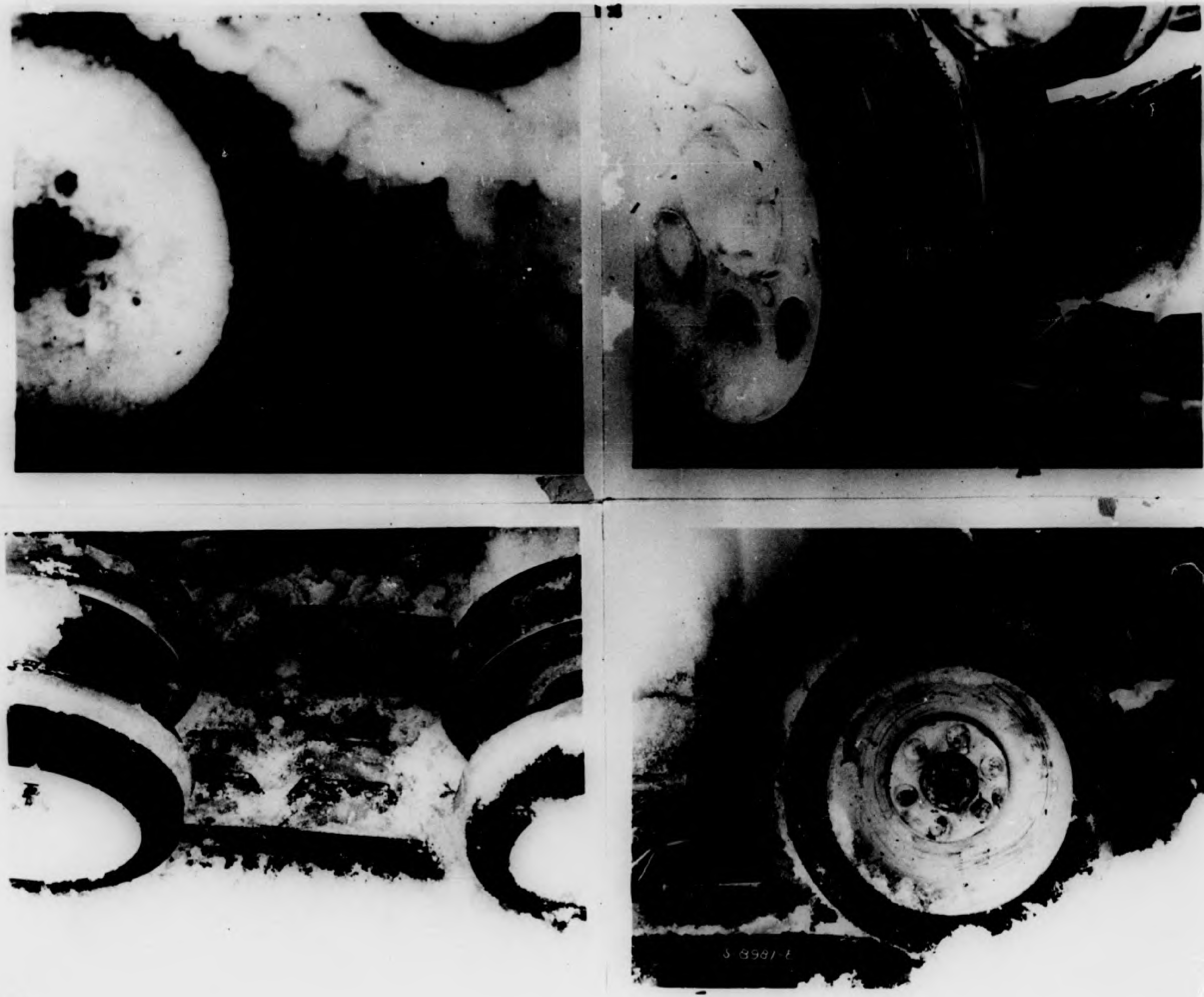


FIG. XV

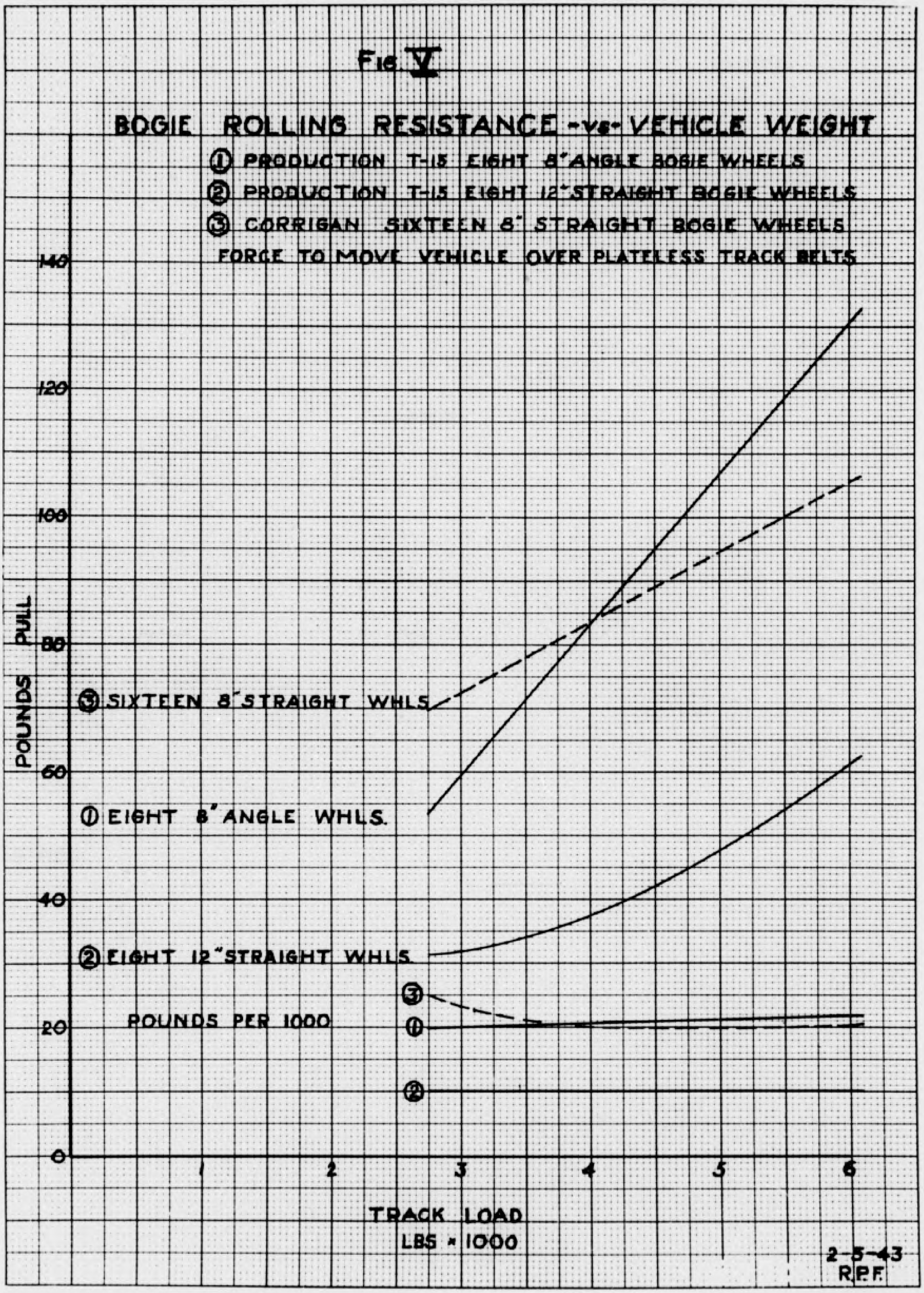


FIG. V
BOGIE ROLLING RESISTANCE -vs- VEHICLE WEIGHT
① PRODUCTION T-15 EIGHT 8" ANGLE BOGIE WHEELS
② PRODUCTION T-15 EIGHT 12" STRAIGHT BOGIE WHEELS
③ CORRIGAN SIXTEEN 8" STRAIGHT BOGIE WHEELS
FORCE TO MOVE VEHICLE OVER PLATELESS TRACK BELTS
POUNDS PULL
140
120
100
80
60
40
20
0
③ SIXTEEN 8" STRAIGHT WHLS
① EIGHT 8" ANGLE WHLS.
② EIGHT 12" STRAIGHT WHLS
POUNDS PER 1000
③
①
②
1
2
3
4
5
6
TRACK LOAD
LBS × 1000
2-5-43
R.P.F.

FIG. XVI

FIG. XVII

CORRECTION

THIS DOCUMENT
HAS BEEN REPHOTOGRAPHED
TO ASSURE LEGIBILITY

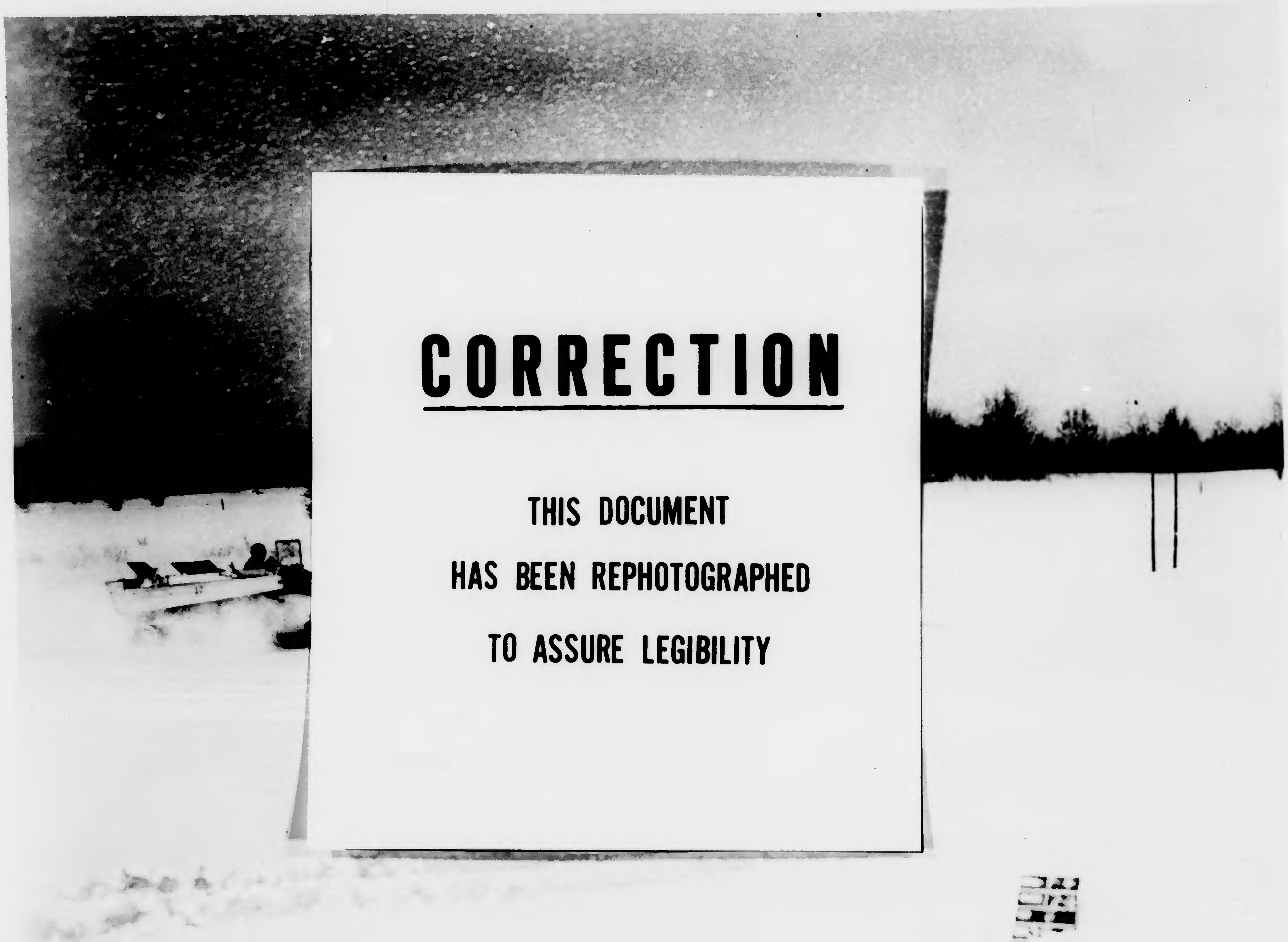


FIG. XVII

FIG. XVII

FIG. XVIII

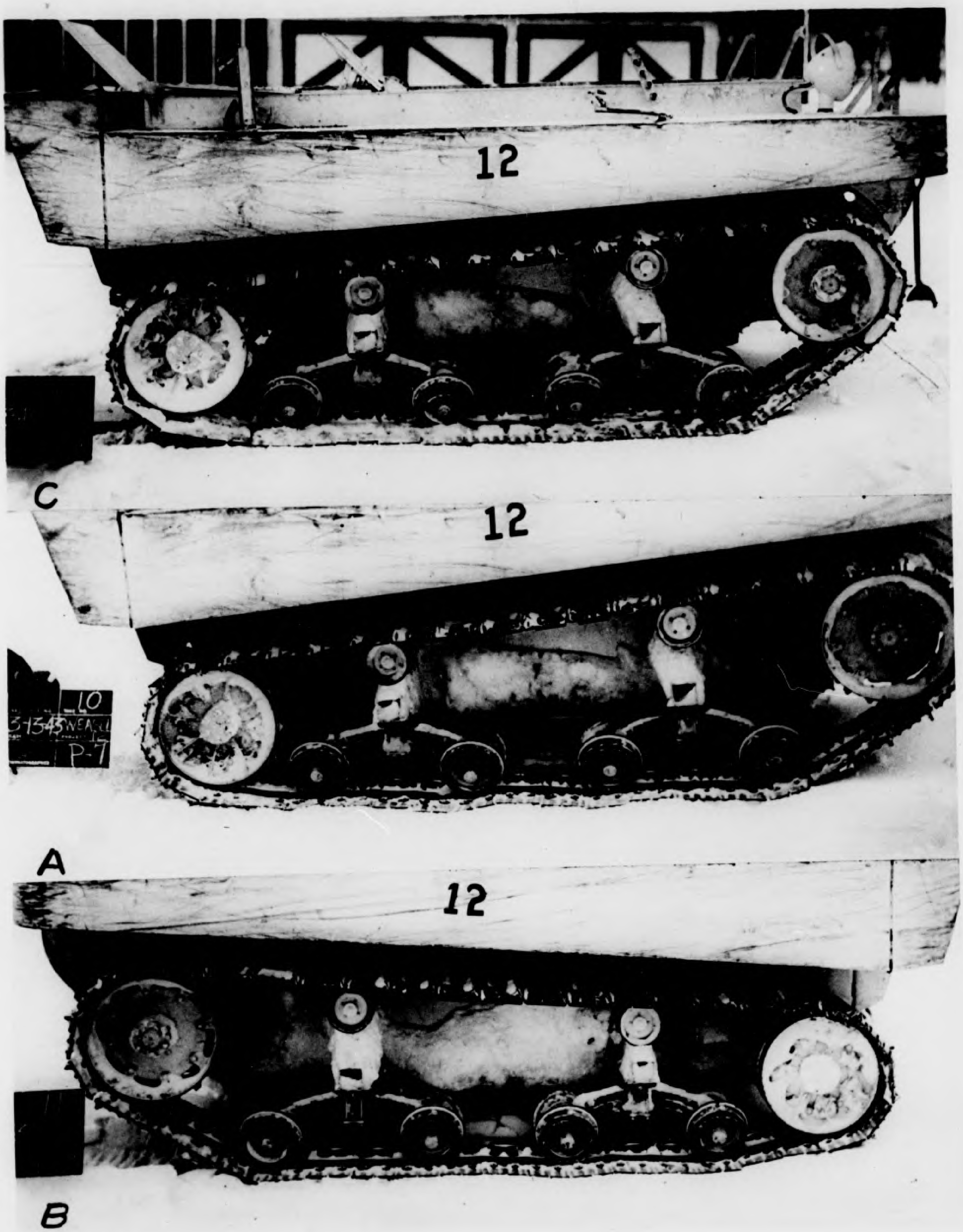
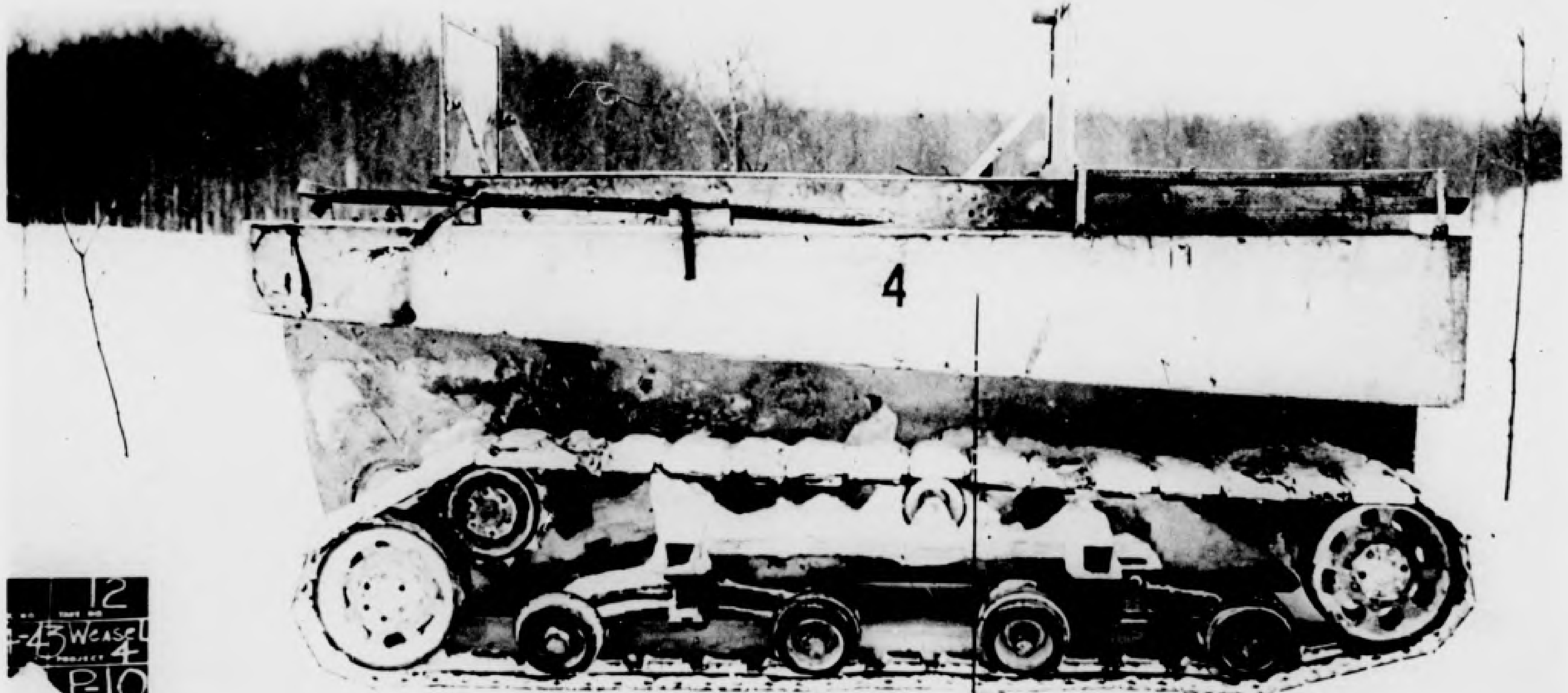
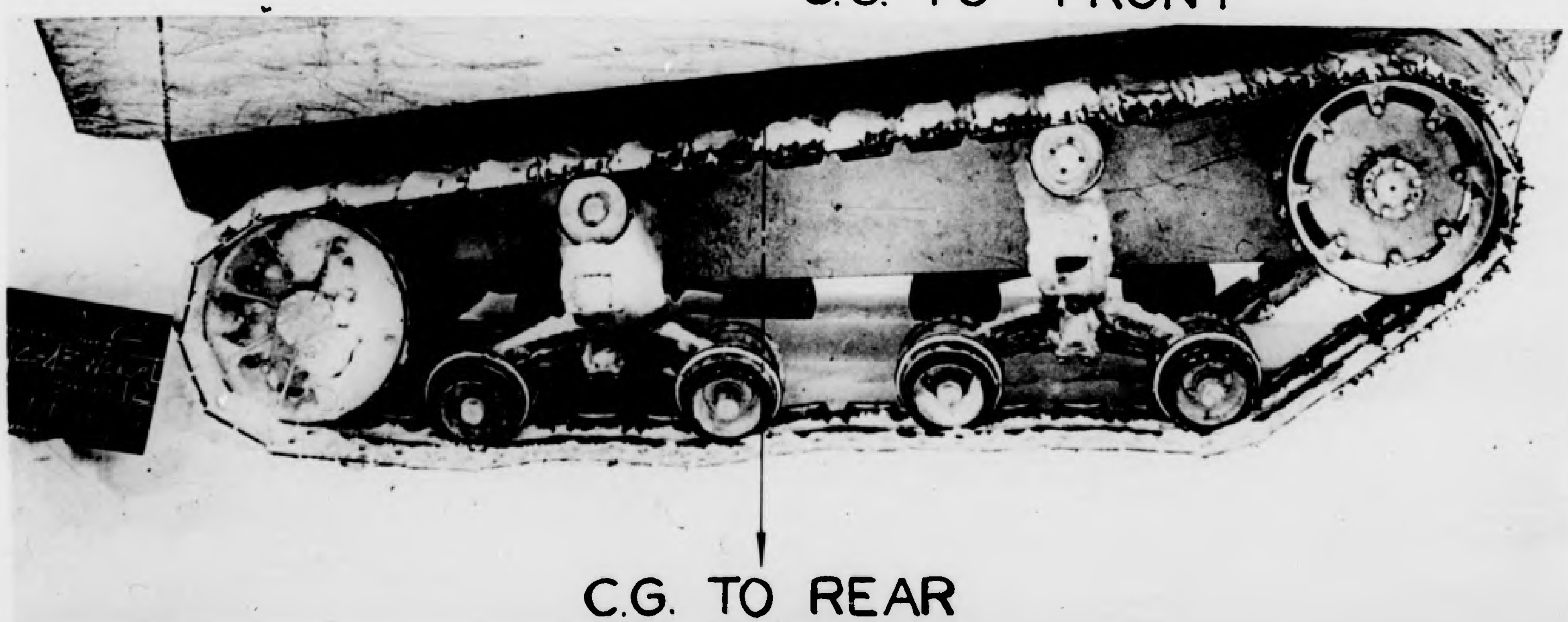


FIG. XIX

FIG. XX



C.G. TO FRONT



C.G. TO REAR

FIG. XXI

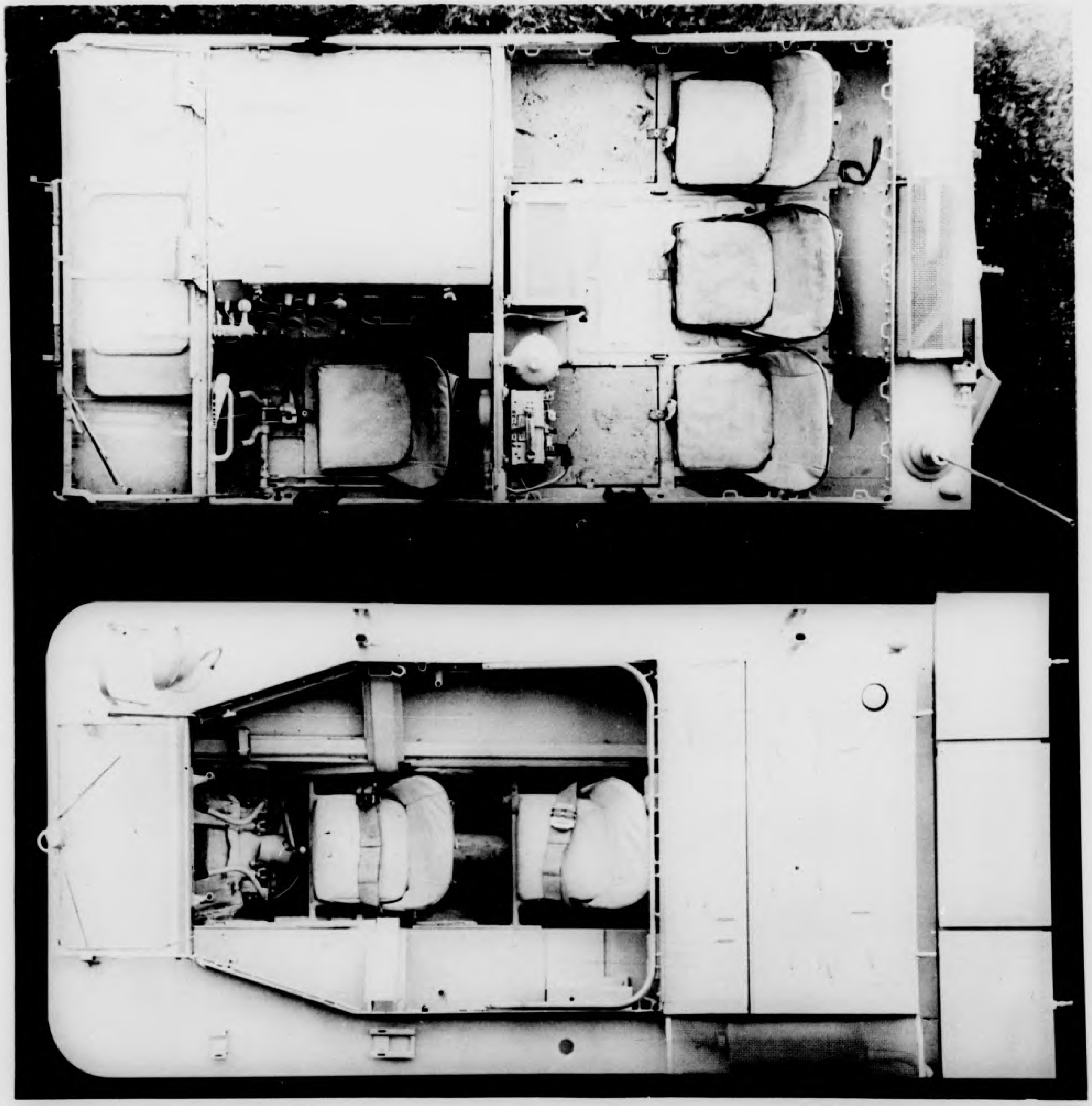


FIG. XXII

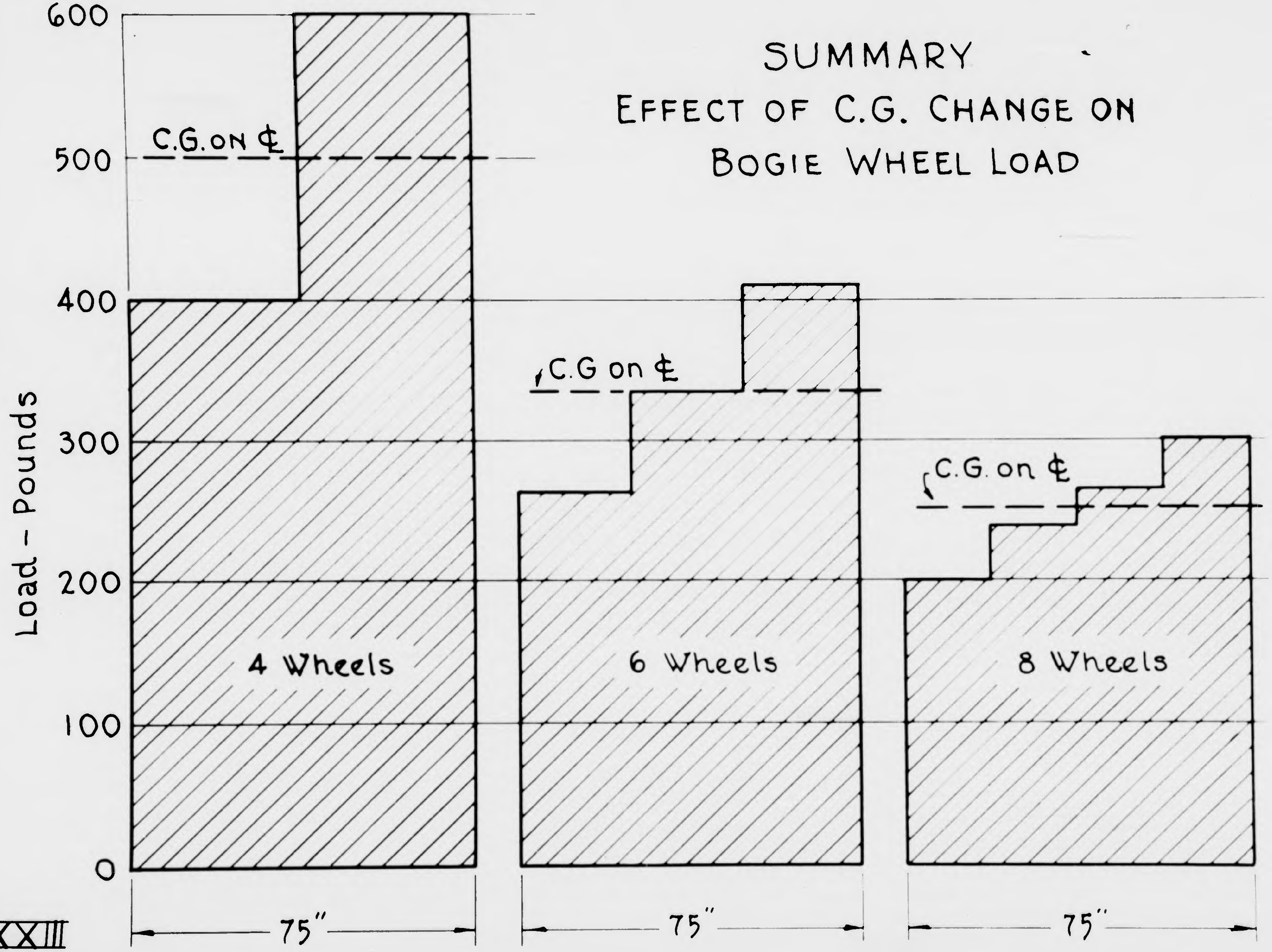

SUMMARY
EFFECT OF C.G. CHANGE ON
BOGIE WHEEL LOAD
600
500
400
300
200
100
0
Load - Pounds
C.G. ON ℄
C.G on ℄
C.G. on ℄
4 Wheels
6 Wheels
8 Wheels
75"
75"
75"

FIG. XXIII

EFFECT OF C.G. CHANGE ON BOGIE WHEEL LOAD

Four Wheels per Side

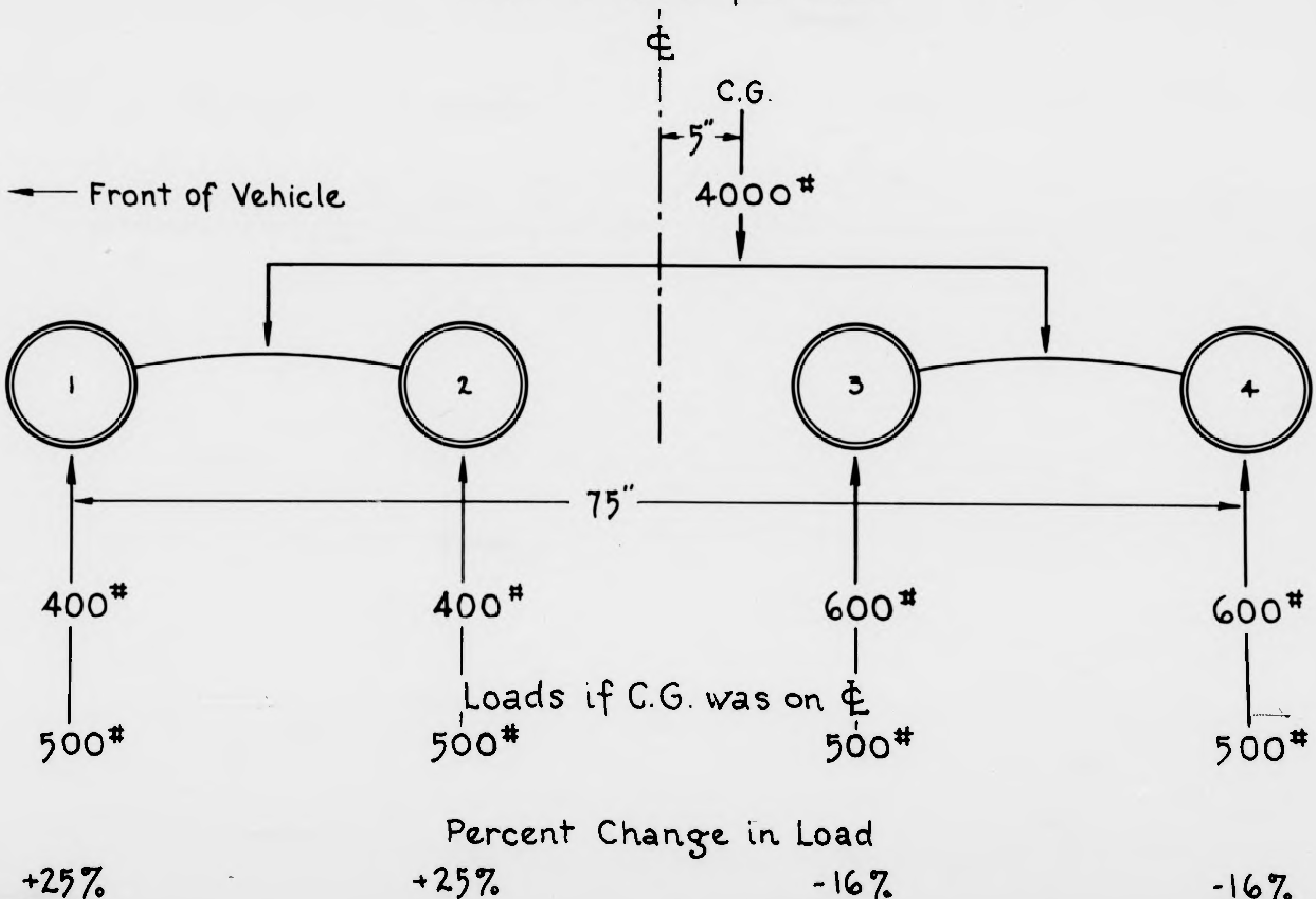


FIG. XXIV

EFFECT OF C.G. CHANGE ON BOGIE WHEEL LOAD

Six Wheels per Side

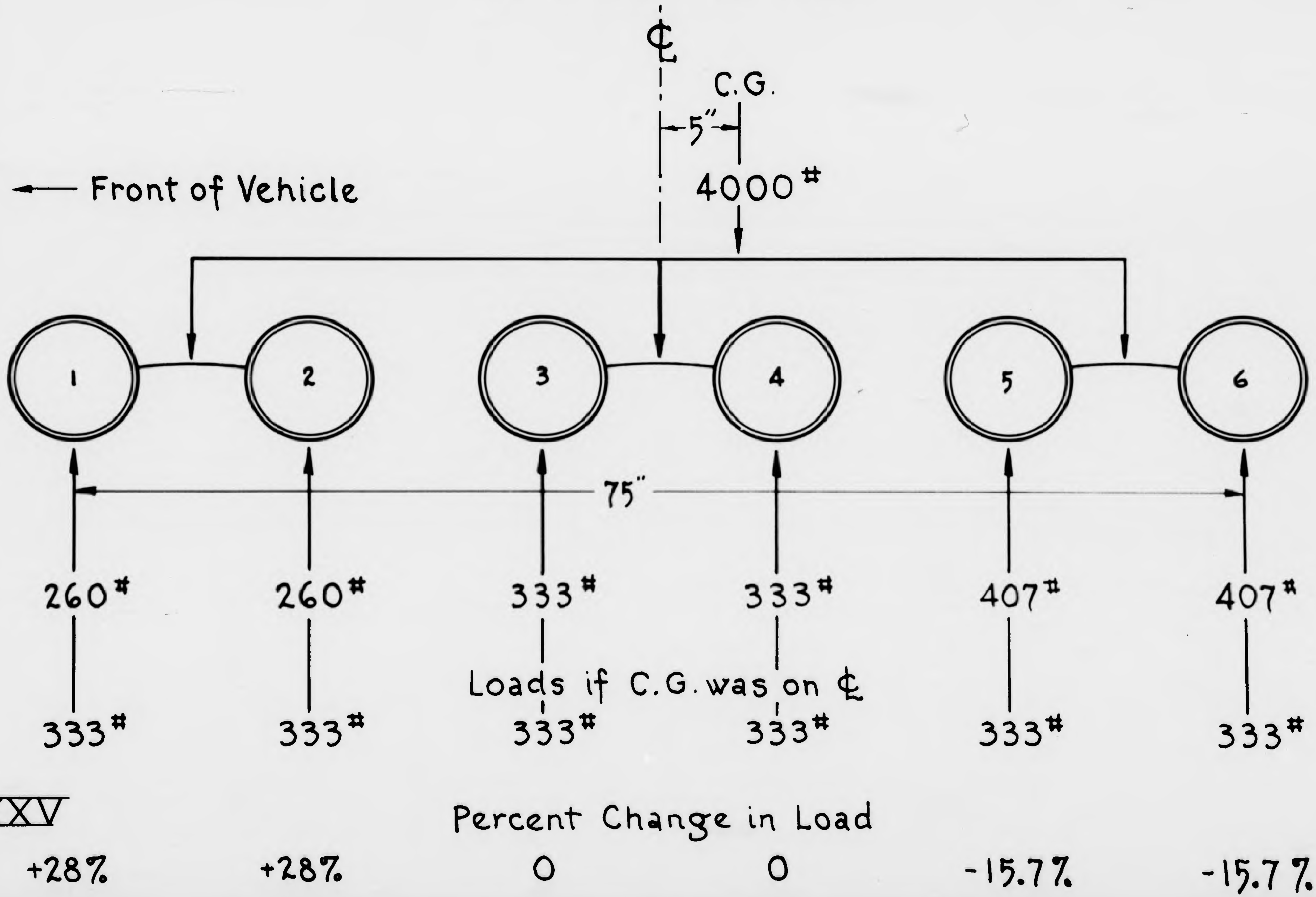


FIG. XXV

EFFECT OF C.G. CHANGE ON BOGIE WHEEL LOAD

Eight Wheels per Side

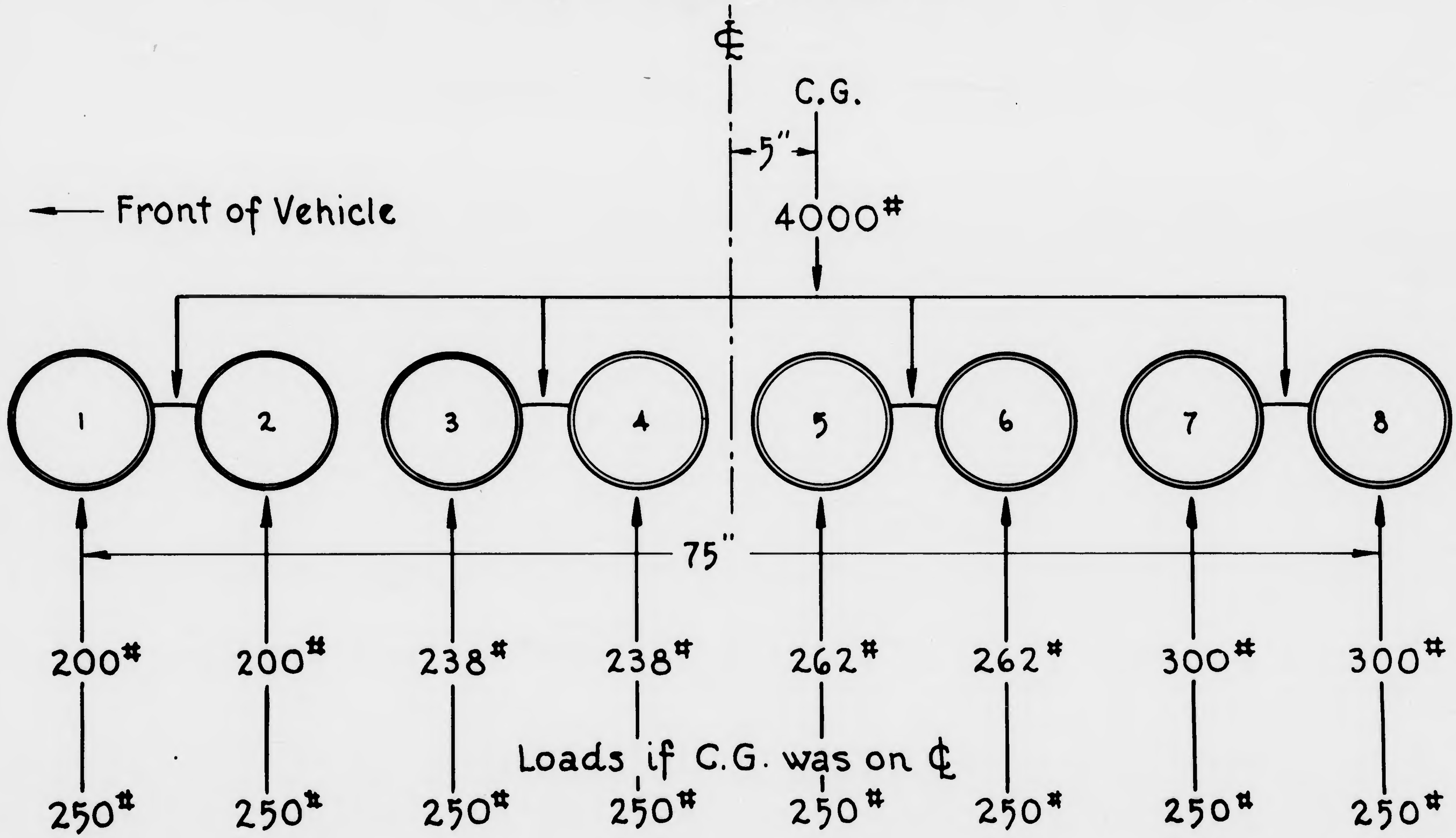


FIG. XXVI

Percent Change in Load

+25% +25% +5% +5% -4.8% -4.8% -15% -15%

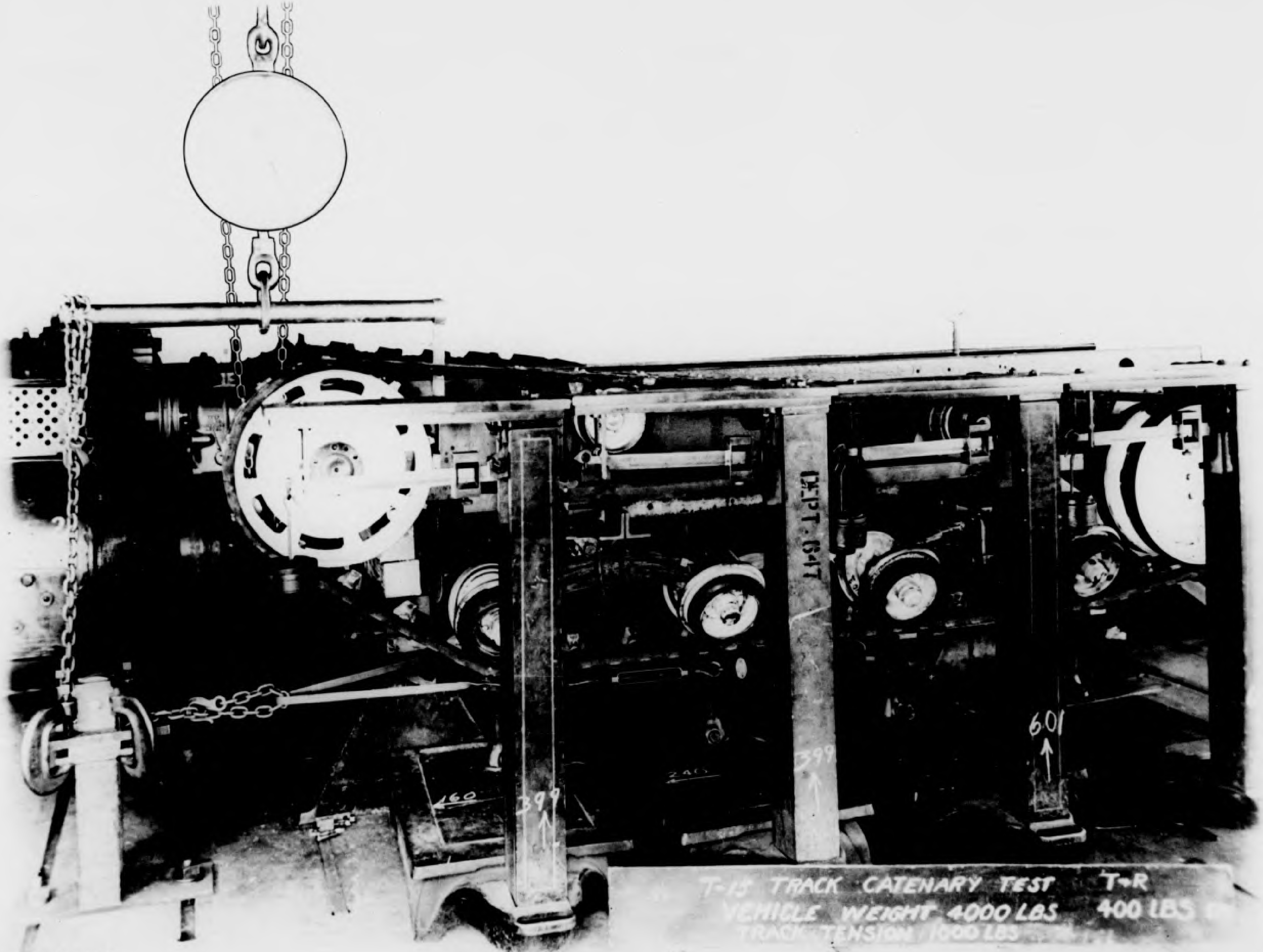
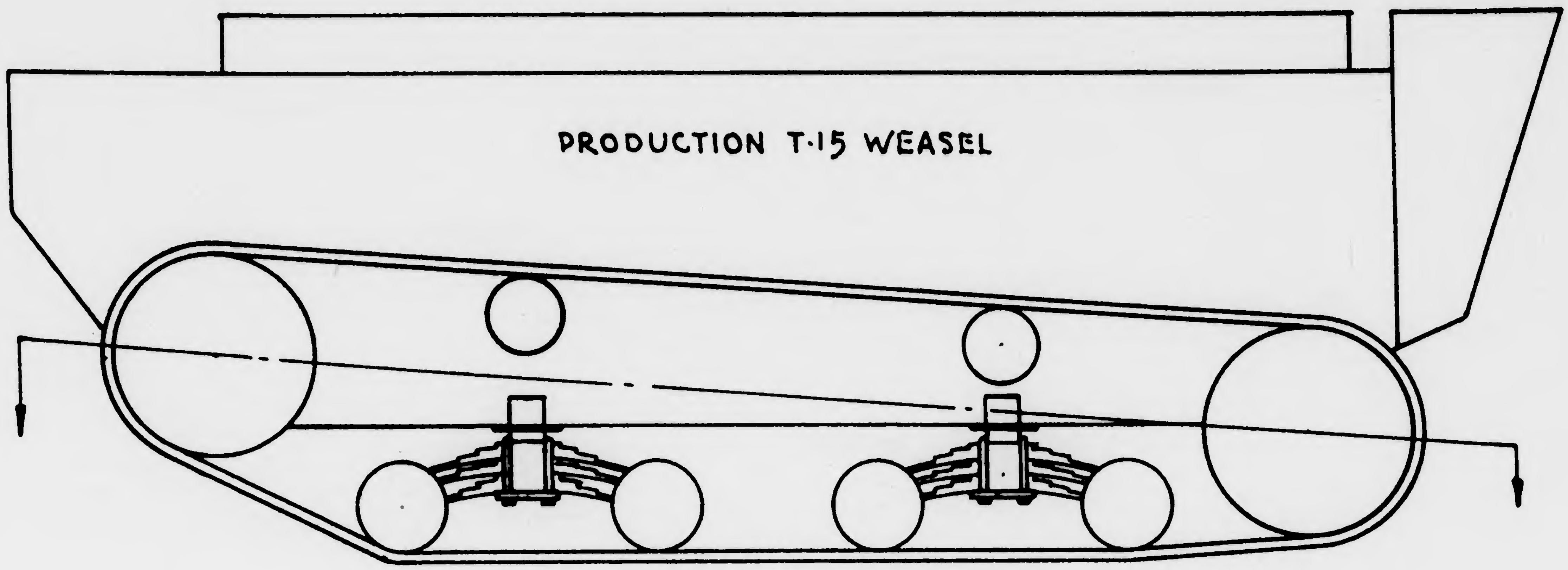

DEPT 647
399
160
240
399
601
T-15 TRACK CATENARY TEST T-R
VEHICLE WEIGHT 4000 LBS 400 LBS
TRACK TENSION 1000 LBS

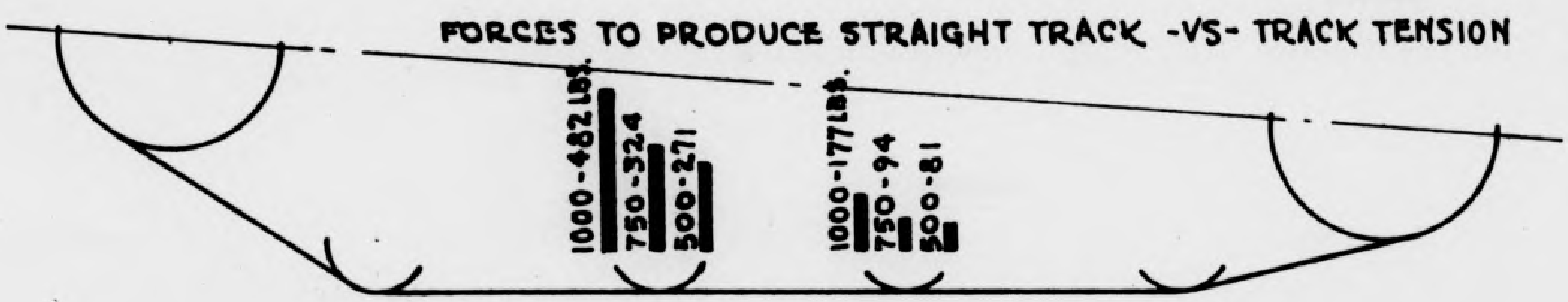
FIG. XXVII

US T-15 TRACK CATENARY TESTS

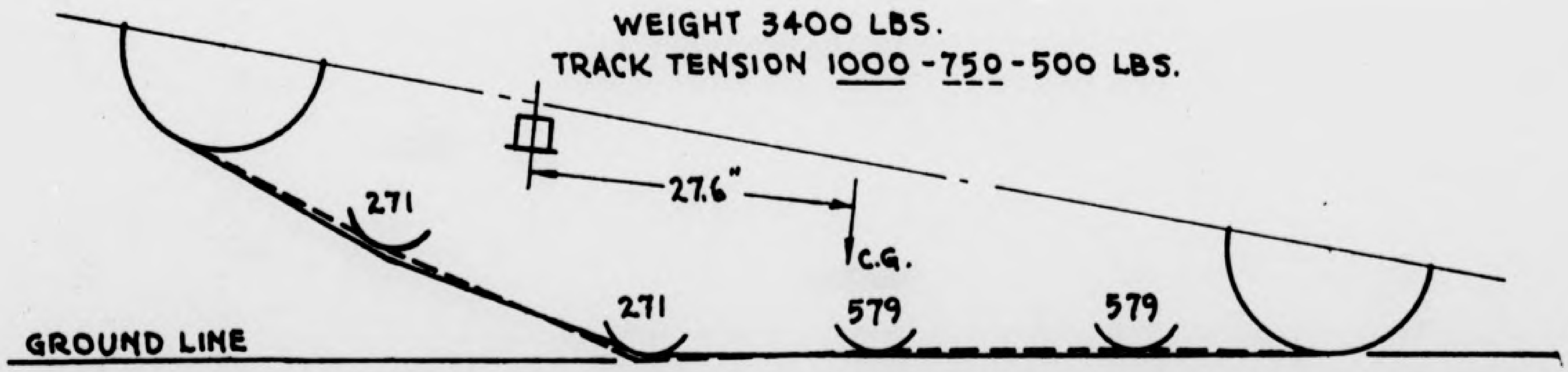


1

2



3

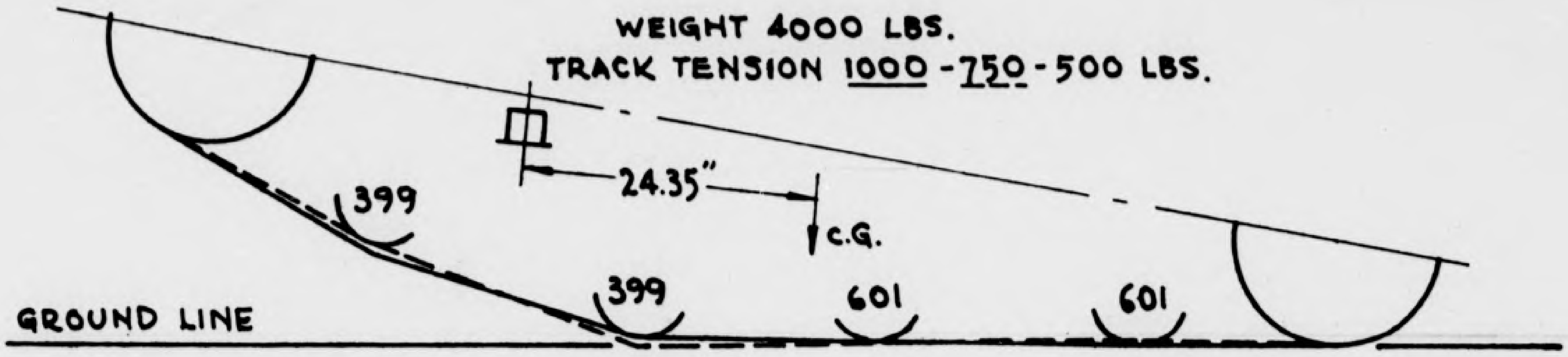


4

500 LBS. T.T. FORM LIES BETWEEN
THE 750 & 1000 T.T. IN FIGS. 4, 5 & 6

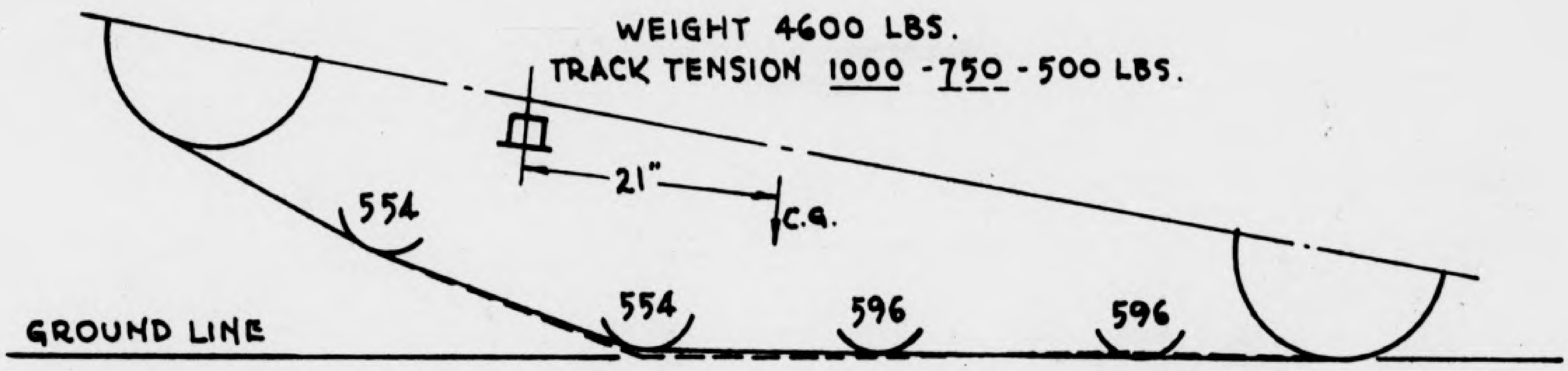
500 LBS. T.T. FORM LIES BETWEEN
THE 750 & 1000 T.T. IN FIGS. 4,5 & 6

WEIGHT 4000 LBS.
TRACK TENSION 1000 - 750 - 500 LBS.



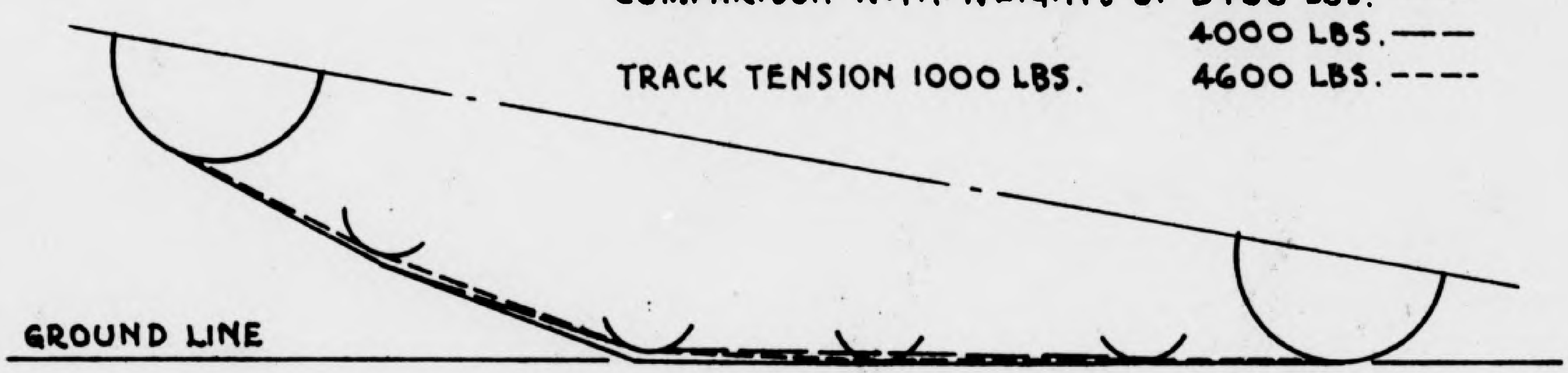
5

WEIGHT 4600 LBS.
TRACK TENSION 1000 - 750 - 500 LBS.



6

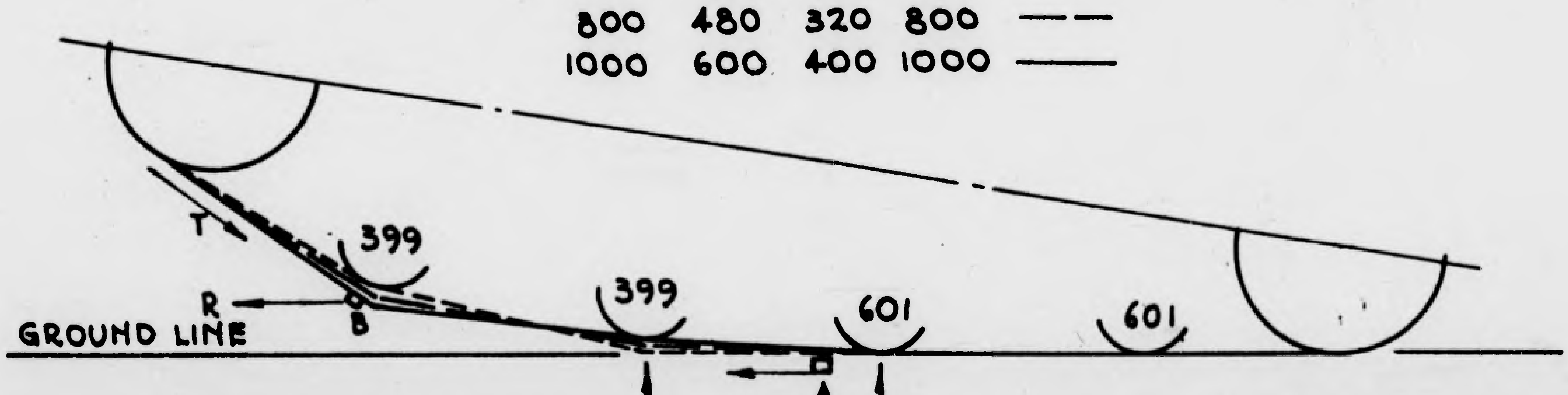
COMPARISON WITH WEIGHTS OF 3400 LBS. ——
4000 LBS. — —
TRACK TENSION 1000 LBS. 4600 LBS. - - - -



7

WEIGHT 4000 LBS.
TRACK TENSION 1000 LBS

T	A	+ B	= R	
400	240	160	400	- - - -
800	480	320	800	— —
1000	600	400	1000	——



8

FOR A STRAIGHT TRACK

T & R EACH

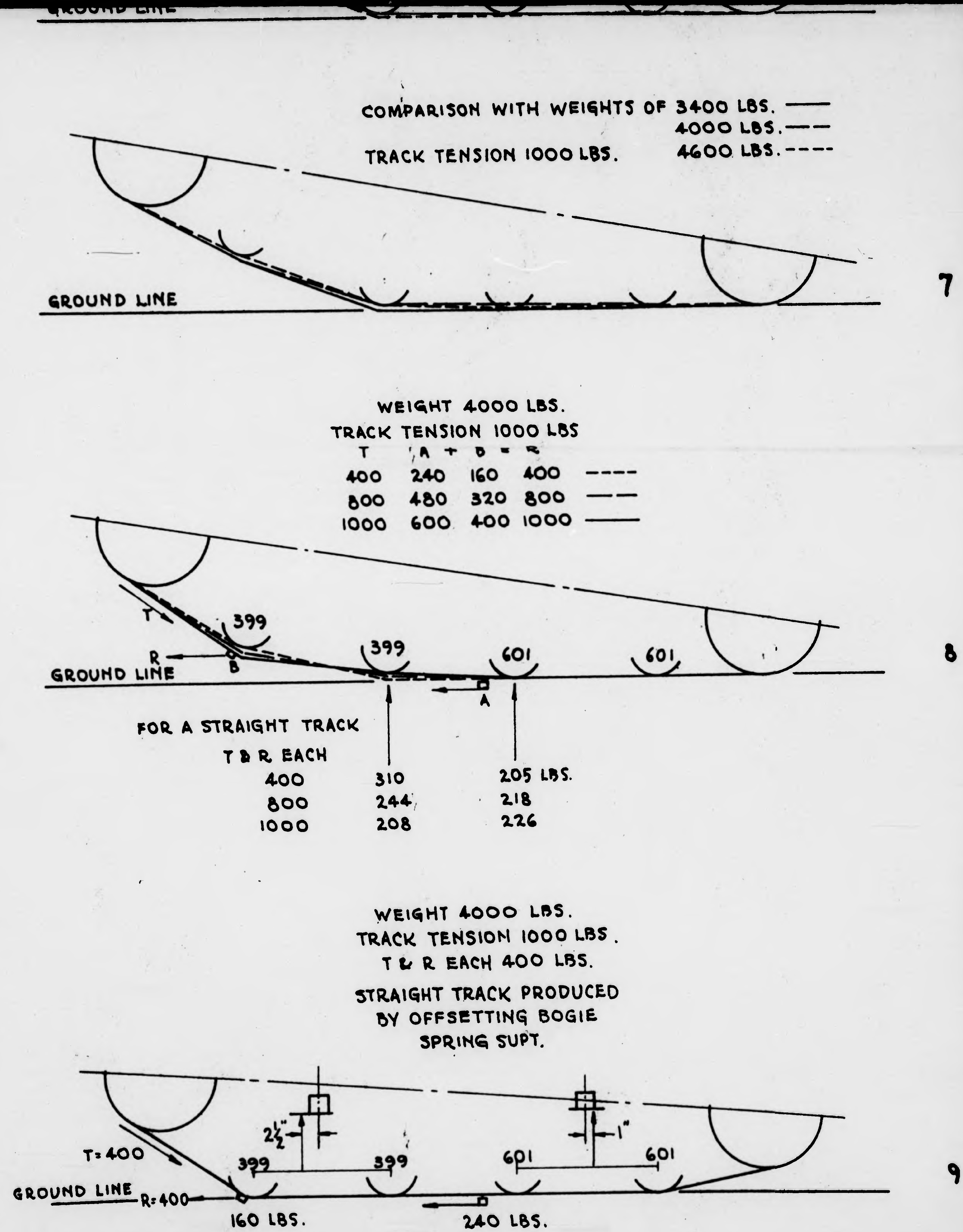
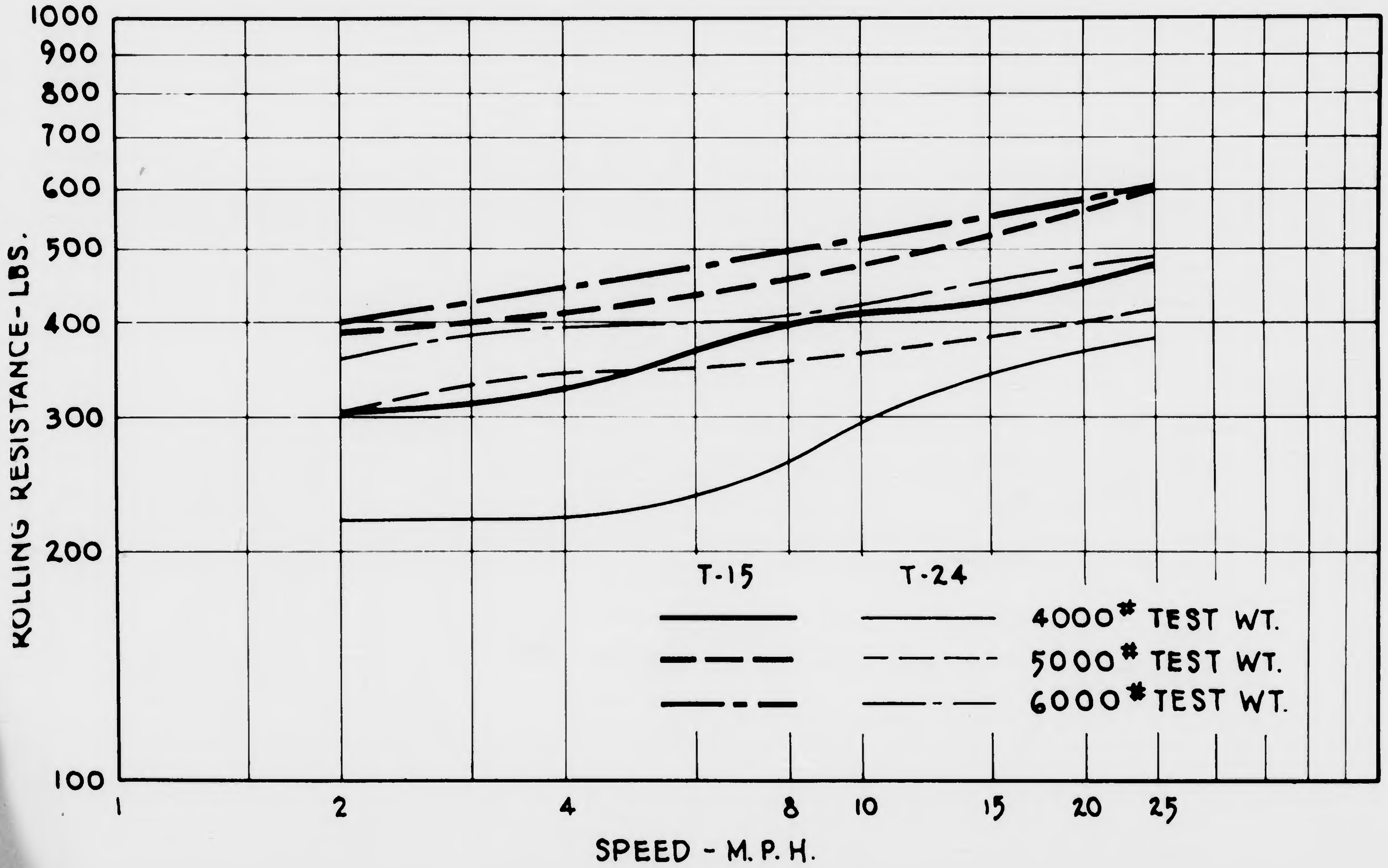
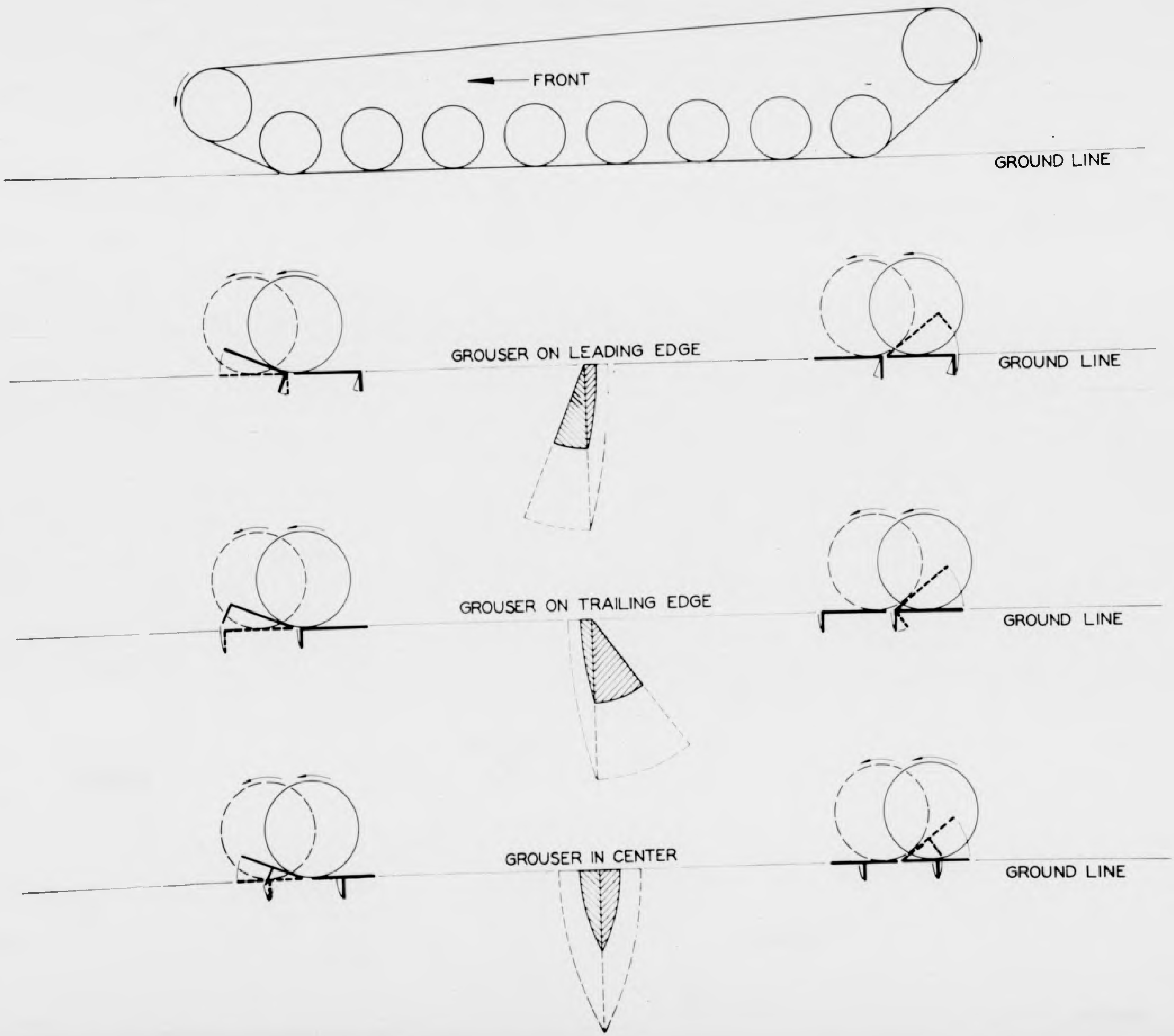

GROUND LINE
COMPARISON WITH WEIGHTS OF 3400 LBS.
4000 LBS.
4600 LBS.
TRACK TENSION 1000 LBS.
GROUND LINE
7
WEIGHT 4000 LBS.
TRACK TENSION 1000 LBS
T A + B = R
400 240 160 400
800 480 320 800
1000 600 400 1000
T
399
R
B
GROUND LINE
399
601
601
A
8
FOR A STRAIGHT TRACK
T & R EACH
400 310 205 LBS.
800 244 218
1000 208 226
WEIGHT 4000 LBS.
TRACK TENSION 1000 LBS.
T & R EACH 400 LBS.
STRAIGHT TRACK PRODUCED
BY OFFSETTING BOGIE
SPRING SUPT.
2½"
1"
T=400
399
399
601
601
GROUND LINE
R=400
160 LBS.
240 LBS.
9

FIG. XXVIII

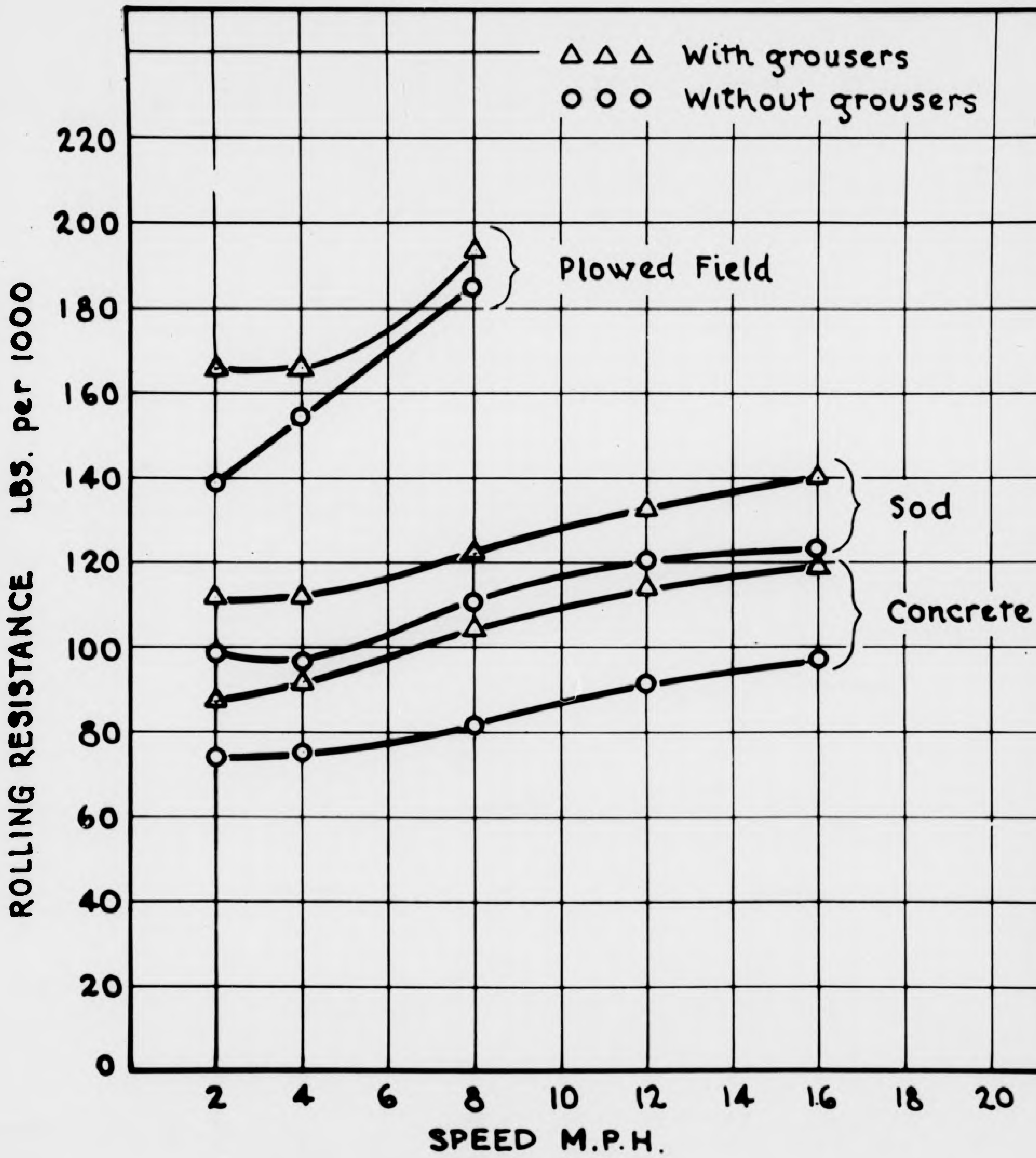
VEHICLE ROLLING RESISTANCE ON PAVEMENT
Production Tracks - 1000# Tension
T-15 vs. T-24



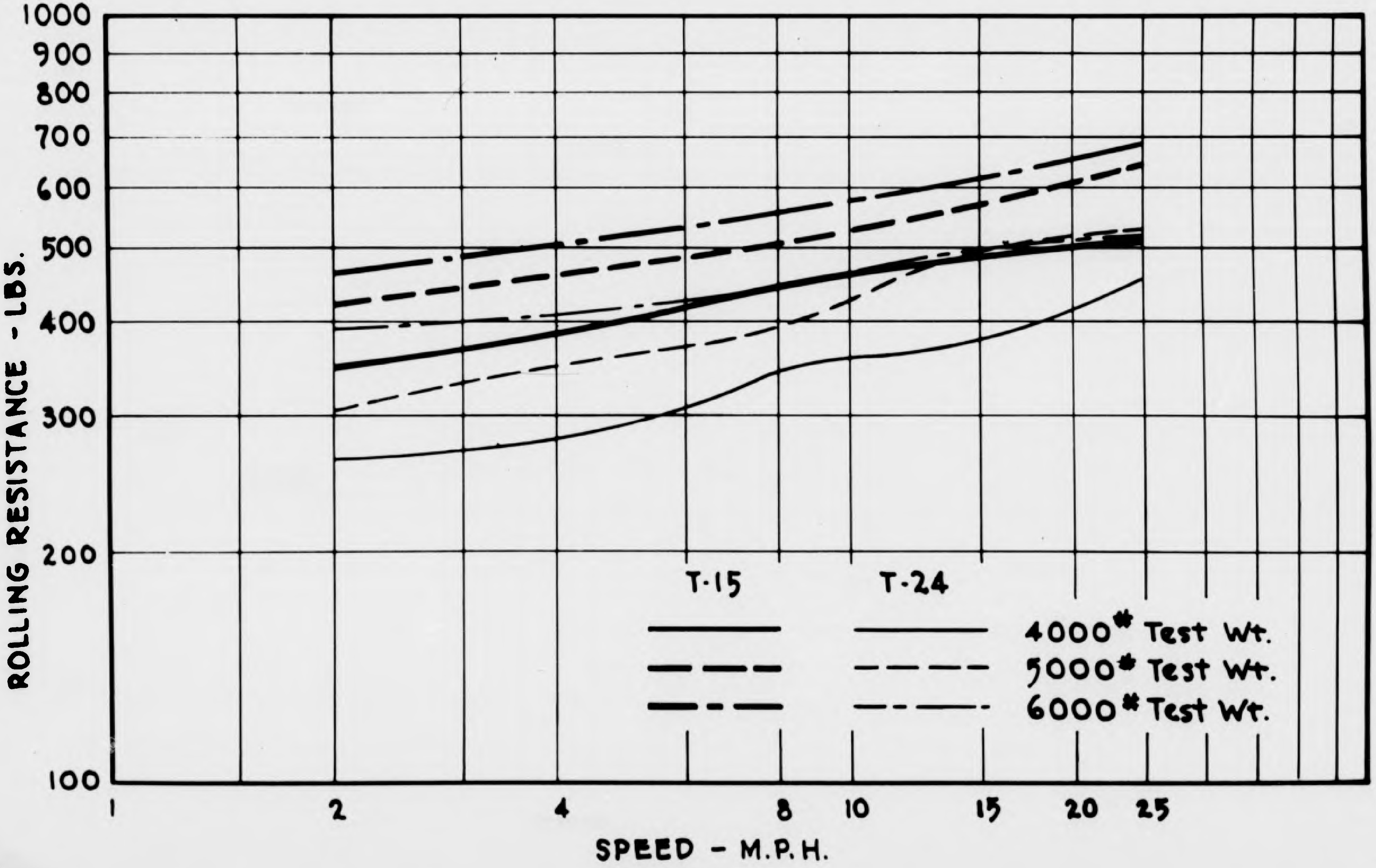
GROUSER LOCATION ANALYSIS

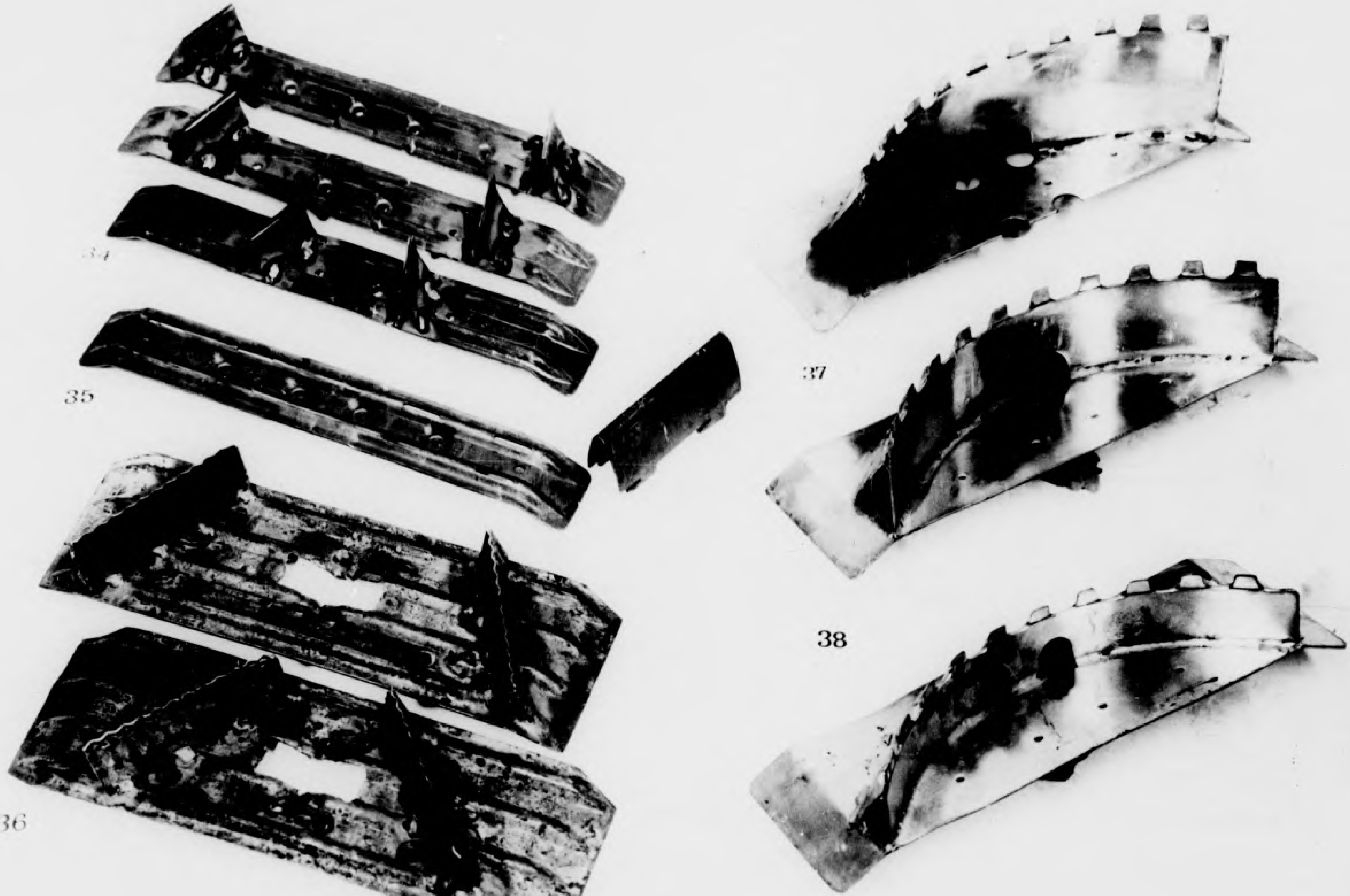


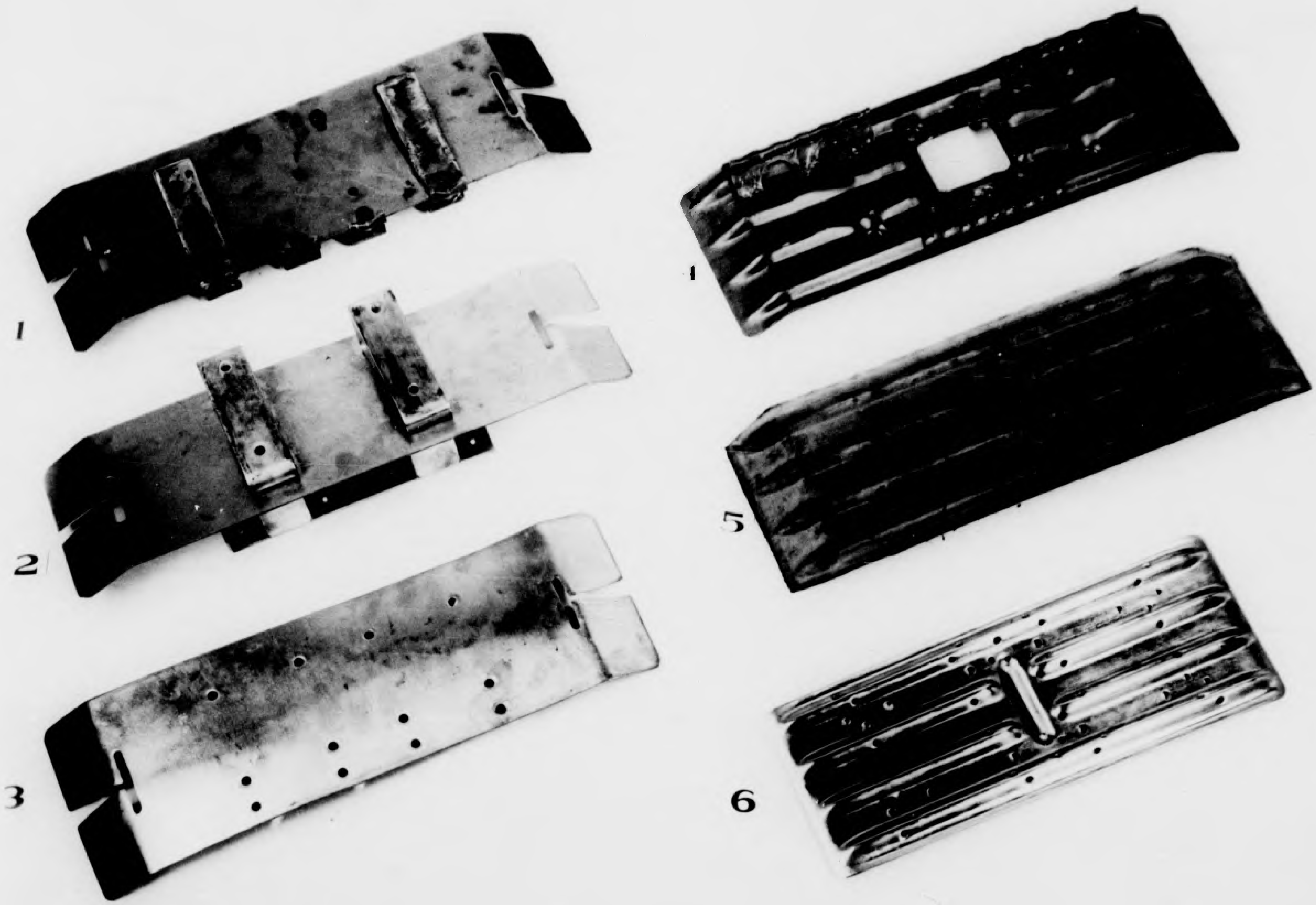
VEHICLE ROLLING RESISTANCE

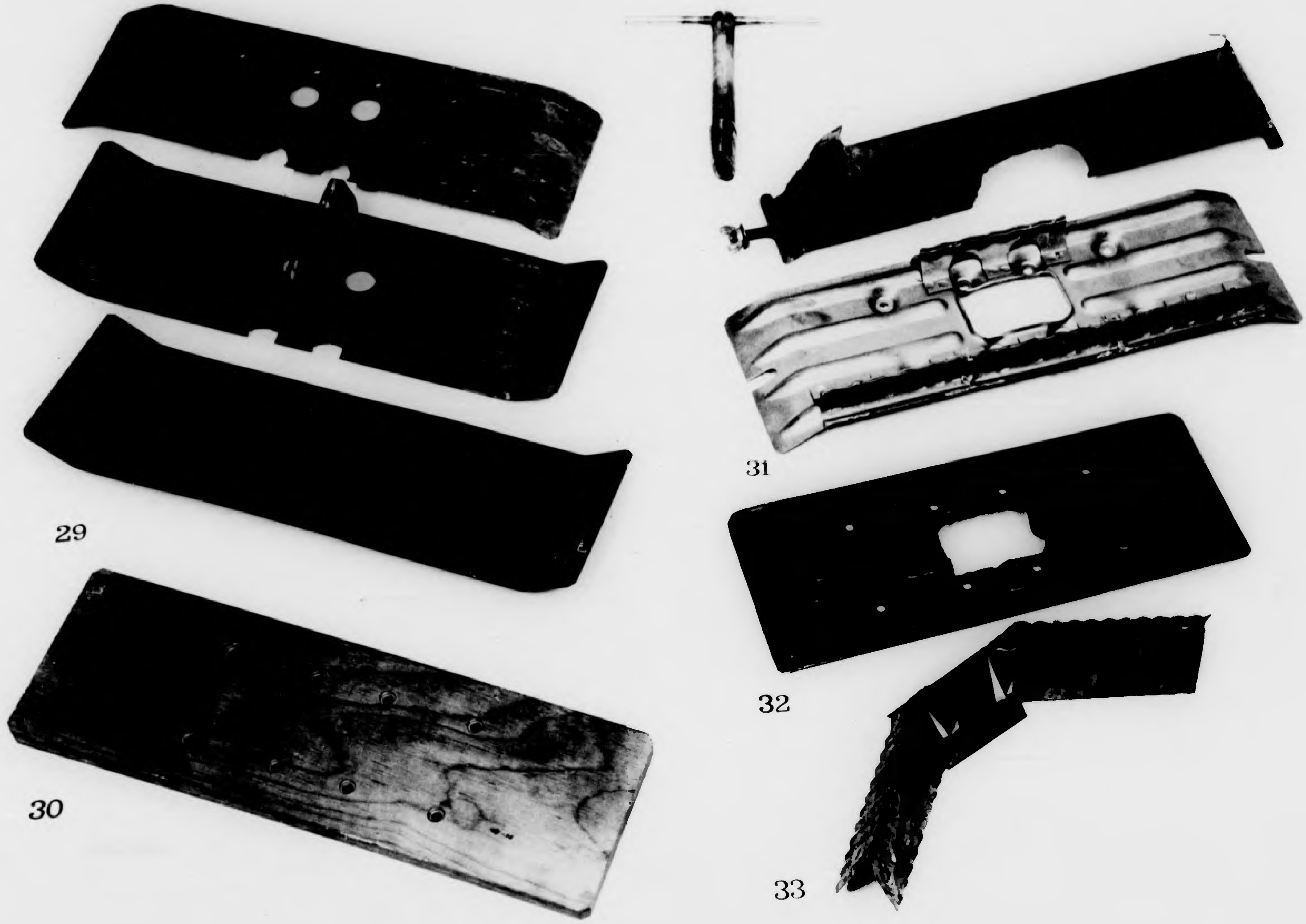


VEHICLE ROLLING RESISTANCE ON GRAVEL
Production Track - 1000# Tension
T-15 vs. T-24




34
35
36
37
38
39


1
2
3
5
6



29

30

31

32

33